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CHARACTERISTICS AND MANAGEMENT OF SOUTHWESTERN PINYON-JUNIPER RANGES: The Status of Our Knowledge

H. W. Springfield









Abstract

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The pinyon-juniper type, characterized by diversity of climate, soils, and topography, covers about 30 million acres in Arizona and New Mexico. The major problem is widespread deterioration of the range resources due to overgrazing and increases in tree density. General guidelines are available for judging the condition and grazing management of pinyon-juniper ranges, as well as for deciding where and how to control the trees for range and wildlife habitat improvement. Although further research is warranted, information is adequate to modify and manage the type to provide an optimum mix of products. These include forage for livestock, and food and habitat for wild animals as the main products; also included are fireplace wood, fenceposts, pinyon nuts, and Christmas trees.

Keywords: Range management, pinyon-juniper type, forage, tree control, *Pinus* sp., *Juniperus* sp.

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CHARACTERISTICS AND MANAGEMENT OF SOUTHWESTERN PINYON-JUNIPER RANGES: The Status of Our Knowledge

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CHARACTERISTICS AND MANAGEMENT OF SOUTHWESTERN PINYON-JUNIPER RANGES: The Status of Our Knowledge

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Highlights

The pinyon-juniper type, characterized by diversity of climate, soils, and topography, covers about 30 million acres in Arizona and New Mexico. It has provided feed for animals, and wood, nuts, and other products for man for centuries. A general problem that overshadows others is widespread deterioration of the range resources due to overgrazing and increases in tree density.

General guidelines are available for judging the condition of pinyon-juniper ranges, as are general guidelines for management. Resting areas from grazing during the growing season at 1- to 3-year intervals has been recommended.

The best use of pinyon-juniper in the foreseeable future is as range for grazing animals. If developed to their potential, pinyon-juniper ranges undoubtedly could furnish forage for more animals. The full potential of these ranges is rarely realized.

More information is available relating to the control of pinyon-juniper than to other aspects of management. Early attempts at cabling produced only transitory benefits. Now, with the experience of past failures and successes, reasonably reliable guidelines have been developed. Responses to control also have been studied in some detail, and situations to be avoided have been pointed out. Because these guidelines are readily available, most land managers are familiar with the various methods and the results to be expected. Careful attention must be paid to site selection and to characteristics of the tree stands in deciding which method to use.

The benefits of pinyon-juniper control have been analyzed in economic terms, but further studies are needed. Projects that are less successful than the best will produce a negative net return. Therefore, considerable planning and forethought should precede any attempts at pinyon-juniper conversion.

Ecological evidence points to suppression of fire as a major factor influencing the spread of juniper in northern Arizona. It seems logical, therefore, that prescribed burning would be a useful tool for converting juniper stands to grassland. Its use has been successfully demonstrated in certain areas.

A fair amount of information is available concerning species and methods for seeding pinyon-juniper ranges. Research results, however, indicate seeding woodland ranges in the Southwest is a risky venture.

The importance of the pinyon-juniper as wildlife habitat is well recognized, mainly for deer, but also for elk, turkey, and other species.

Shrub abundance is a key factor influencing the use of pinyon-juniper ranges by game animals. Recommendations for improving wildlife habitat are to control trees on the more gentle terrain (less than 15 percent slope) and deeper soil, and leave the ridges and steeper slopes untreated, especially the northeast slopes.

Only limited information is available concerning the effects of grazing on runoff and erosion from pinyon-juniper ranges. As a general rule, replacement of pinyon-juniper by grass results in less soil loss but the effects on water yield are negligible.

Coordinating the various land uses holds promise of improving the management of pinyon-juniper in the Southwest. Utilization of wood products is related either directly or indirectly to the production or recovery of the other woodland resources.

In the final analysis, the evidence suggests the pinyon-juniper type in the Southwest can be modified and managed for an optimum mix of products: forage for livestock, and habitat and food for wild animals are the main products; important also are fireplace wood, fenceposts, pinyon nuts, Christmas trees, and esthetically pleasing surroundings—for recreation and living—for people.

Physical Characteristics

The pinyon-juniper type covers about 30 million acres in Arizona and New Mexico (Aldon and Springfield 1973). It is widely distributed over the north half of Arizona, and throughout all except southeast and south-central New Mexico (fig. 1). The type is characterized by pinyon pine,[2] one-seed juniper, and Utah juniper. Blue grama is the most common understory species.

Pinyon-juniper ranges in the Southwest have been grazed by domestic livestock for more than 200 years. For centuries the trees have provided people with fuelwood, posts, poles, and pinyon nuts. Pressures on the resources have been most intense immediately adjacent to the settlements scattered throughout the type, but all pinyon-juniper ranges in the two States, even those rather remote from towns, have had a long history of use.

Although mainly important as range for domestic livestock and habitat for wildlife, pinyon-juniper also has forest, watershed, and recreation values.

[2]Common and botanical names of plants mentioned are listed at the end of this Paper.

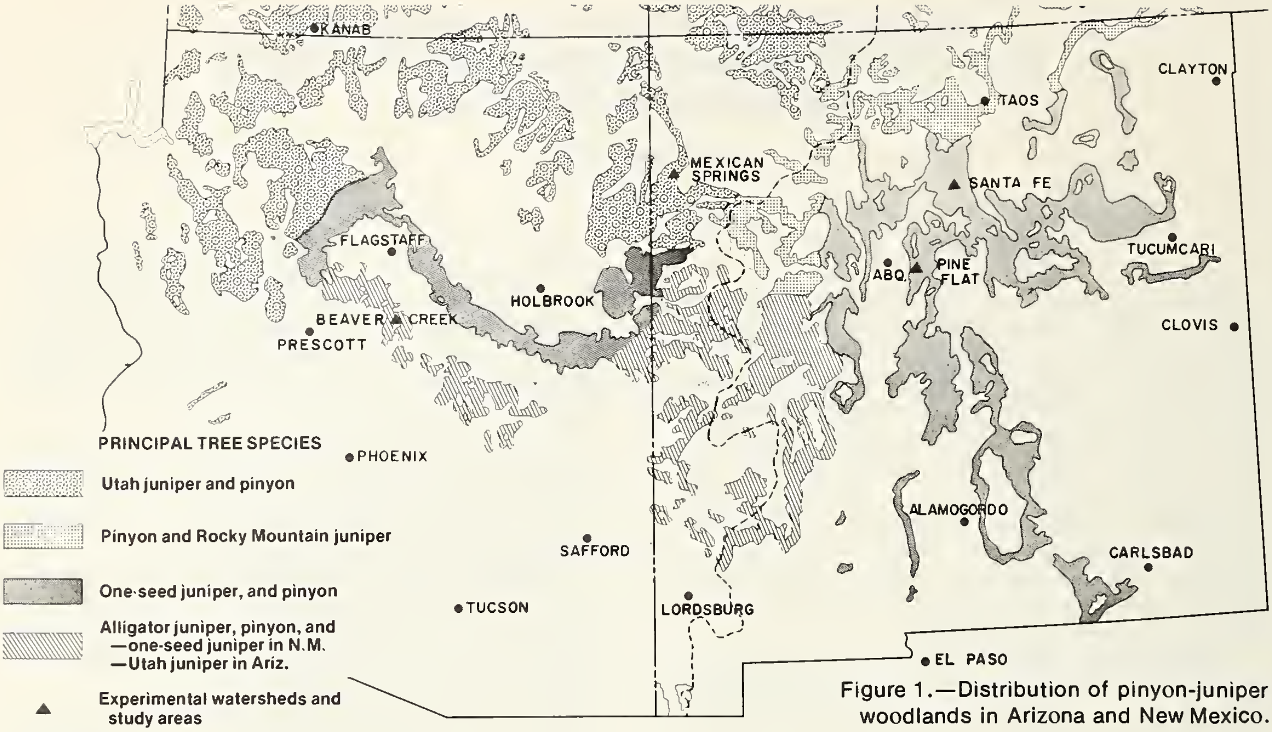

Figure 1.—Distribution of pinyon-juniper woodlands in Arizona and New Mexico.

The pinyon-juniper type generally is found at elevations from 4,500 to 7,500 feet. At the upper limits of its range, the type mixes with Gambel oak and ponderosa pine; at its lower limits it blends with grassland, oak woodland, or desert shrub. Density of the tree stands varies. In a few areas, the trees are so dense that practically no understory exists. Such areas, usually dominated by pinyon, have little if any value for grazing. At the other extreme are areas where the trees—usually junipers—are widely spaced, and the aspect is savanna with a cover of herbaceous or shrubby plants (fig. 2).

Thirty-two percent of the National Forest lands in New Mexico support pinyon-juniper (Aldon and Brown 1971). More than 24 percent of each Forest entirely within the State is in this type; 46 percent of the Cibola is classed as woodland:

National Forest	Size (USDA-FS 1970)	Pinyon-juniper woodland type	
	(Acres)	*(Acres)*	*(Percent)*
Apache (large portion in Ariz.)	616,328	150,270	24.4
Carson	1,440,919	394,616	27.4
Cibola	1,594,086	732,550	46.0
Coronado (large portion in Ariz.)	69,567	6,744	9.7
Gila	2,702,643	931,164	34.4
Lincoln	1,103,220	269,050	24.4
Santa Fe	1,468,999	358,926	24.4
Total	8,995,762	2,843,320	32.0

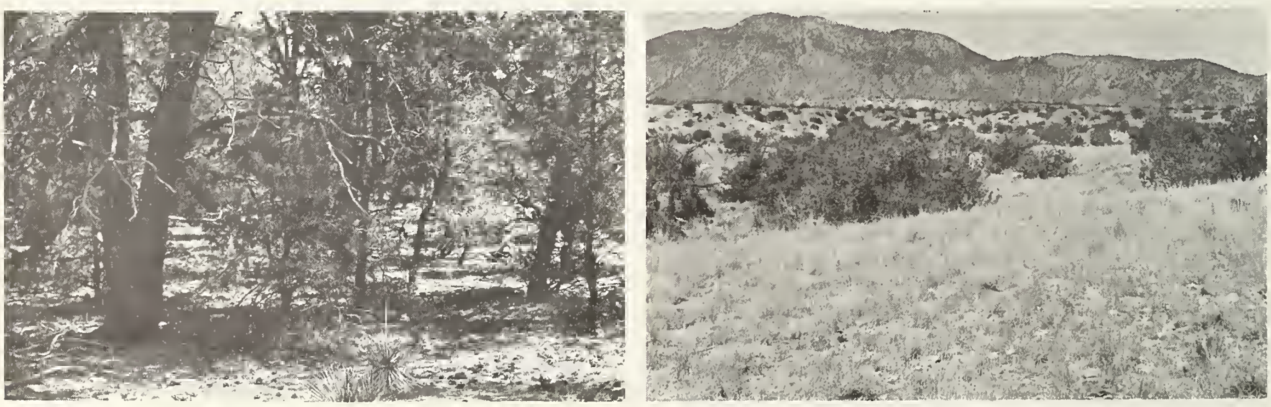

Figure 2.—**Left**, Dense stand of pinyon with practically no herbaceous understory; **Right**, open stand of trees with good grass cover.

Climate

Annual precipitation usually is from 12 to 22 inches. The more open stands receive 12 to 14 inches, whereas the denser stands may receive 16 to 22 inches of rain and snow. Seasonal distribution varies; for example, in eastern New Mexico 75 percent of the year's precipitation falls during the growing season (April through September) compared with only 45 percent in western Arizona.

Winter storms come mainly from the Pacific and move eastward. As these storms move inland they drop most of their moisture on the mountains of central Arizona. The most prominent feature is the Mogollon Rim, which has wet winter climate on the windward side and a dry winter climate on the lee side (Jameson 1969). These California storms have lost much of their moisture by the time they reach New Mexico.

Summer storms originate from the Gulf of Mexico and travel northwest across New Mexico into Arizona. The effect of this summer monsoon decreases toward the northern part of the two States. Because much of the summer rain falls as a result of convectional storms, the higher elevations receive the higher rainfall.

Differences in precipitation patterns are reflected in the vegetation. Eastern New Mexico gets the bulk of its precipitation during warm weather, and the vegetation is typically Great Plains grassland. The various grassland communities form broad ecotones with pinyon-juniper woodland. At the other extreme in northern Arizona, much of the precipitation comes from cold winter storms and the vegetation shows affinities to the Great Basin.

The proportion of winter-to-summer precipitation varies according to local topography and elevation, as well as geographic location. Lavin originally classified the climate of the pinyon-juniper type in 1953 (USDA-FS 1953, p. 12-14). His classification, slightly revised in 1964 (personal communication), is as follows:

Climate	Precipitation		
	Winter	Summer	Total
		(*Inches*)	
Cool, moist	9-11	7- 9	16-20
Warm, moist	10-13	6- 9	16-22
Cool, winter dry	5- 7	7- 9	12-16
Warm, winter dry	4- 7	8-11	12-18
Cold, winter dry	4- 6	8-10	12-16
Cold, summer dry	7- 9	4- 6	11-15
Warm, summer dry	7- 9	4- 6	11-15

This classification has been helpful in delineating various pinyon-juniper subtypes and zones for revegetation.

Snow rarely reaches great depth in the pinyon-juniper except at the higher elevations and in the northern parts of the two States. Moreover, the snow usually melts in a few days, especially on south-facing slopes. Only in exceptional winters, perhaps once in 10 years, do the depth and persistence of snow on pinyon-juniper ranges cause problems for ranchers.

Geology and Soils

Pinyon-juniper is found on a wide variety of soils and parent materials. Within the National Forests of Arizona and New Mexico, soils supporting pinyon-juniper vary in texture from stony, cobbly, and gravelly sandy loams to clay loam and clay, and in depth from shallow to deep. Parent materials likewise vary widely from granite, basalt, limestone, and sandstone to mixed alluvium.

Volcanic parent material is common throughout the pinyon-juniper woodland of both States. From these materials, the Cabezon, Gem, and Springerville soils have formed. Limestones are relatively more abundant in Arizona than in New Mexico. Some of the more common limestone-derived soils are La Porta, Purner, Tortugas, and Winona.

About 32 percent of the pinyon-juniper of Arizona is on soils formed from basalt, much of which has developed into Gem (Thunderbird) and Springerville soils (Jameson and Dodd 1969). An area of similar size (29 percent) is underlain by Kaibab and Redwall limestones, much of which in turn developed into Tortugas and Winona soils. Soil characteristics for various geologic parent materials are as follows:[3]

Parent material	Infiltration capacity	Moisture-holding capacity	Fertility
Jurassic sandstones	High	Low	Low
Supai sandstones	Medium	Medium	Low
Coconino sandstones	High	Low	Low
Kaibab limestone	High	Low	Low
Redwall limestone	Medium	Medium	Medium
Triassic shales	Low	High	Low
Mesa Verde formation	Medium	Medium	Medium
Tertiary volcanics (basalt)	Medium	High	High
Quaternary volcanics	Medium to high	Low to high	Low to high
Granite	High	Low	Low
Sand and gravel	High	Low	Low

Nearly a third of the pinyon-juniper ranges within the National Forests of New Mexico are on highly unstable geologic formations (Aldon and Brown 1971). Sedimentary units make up 54 percent of the acreage, igneous units 39 percent, and Precambrian

[3]*Jameson, Donald A. 1967. Productive potential of sites in the pinyon-juniper type. (Establishment and progress report on file at Rocky Mt. For. and Range Exp. Stn., Flagstaff, Ariz.)*

igneous and metamorphic formations 7 percent. The Datil formation, a high sediment producer, makes up 27 percent of the Cibola woodland and 42 percent of the Gila woodland.

Jameson[3] listed herbage production potentials for various soils in northern Arizona as follows:

Parent material	Soil series	Production potential (*Lb/acre*)
Basalt	Thunderbird	1,200-1,400
Kaibab limestone	Crater:	
	shallow	1,000-1,200
	very shallow	600- 800
Moenkopi shale	Tours	1,200-1,500
	Moenkopi	500- 800
Chinle shale	Chinle	500- 800

Herbage production on Springerville soils was similar to that on Gem (Thunderbird) and Tortugas soils when there were few trees (Jameson and Dodd 1969), but the Springerville soils produce much less perennial vegetation than the other soils when there is appreciable tree cover.

Ecological Characteristics

Communities

Several pinyon-juniper communities or subtypes have been recognized (see fig. 1). Pinyon is proportionately more abundant than junipers at the higher elevations and in the northern portions of Arizona and New Mexico (fig. 3). Pinyon is replaced by Mexican pinyon in extreme southern New Mexico and southwestern Arizona, and by singleleaf pinyon in extreme northwestern Arizona.

Throughout most of the type, junipers outnumber pinyons. One-seed juniper is widely distributed in New Mexico, but virtually absent from northeastern and northwestern Arizona. Just north of the Mogollon Rim it forms a belt in mixture with pinyon. South of the Mogollon Rim, the dominant species at the higher elevations is alligator juniper, which is common in southern and western New Mexico. Utah juniper is widespread in Arizona, but occurs only in the northwestern part of New Mexico. Rocky Mountain juniper is common in northern New Mexico at elevations above 6,000 feet.

Utah juniper is the dominant species in three of four subtypes recognized in northern Arizona and New Mexico (west of the Continental Divide) by Jameson[3] (table 1). According to Jameson, high-producing areas are in the higher elevations of the warm moist zone, where grasses such as sideoats grama and bottlebrush squirreltail are common. Low-producing areas are in the cool, winter-dry zone characterized mainly by blue grama.

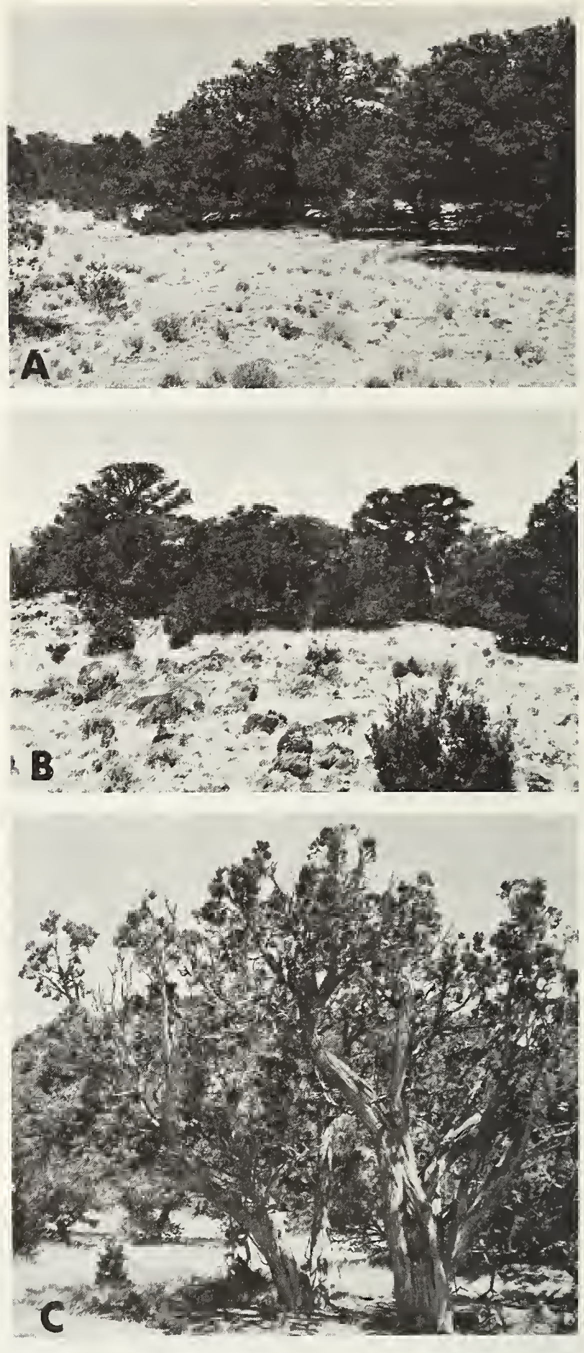

Figure 3.—The occurrence of pinyon and the junipers ranges from relative dense, pure stands of pinyon **(A)**, to intermixtures of the species **(B)**. At lower elevations, Utah juniper forms extensive open stands **(C)**. Alligator juniper occurs in both the pinyon-juniper type and throughout the lower pine type (from Barger and Ffolliott 1972).

Ecological studies of 71 pinyon-juniper sites in northern Arizona and northwestern New Mexico showed the following principal species (Daniel et al. 1966):

Table 1.--Description of four subtypes in pinyon-juniper woodland in northern Arizona and New Mexico (west of the Continental Divide) as recognized by Jameson[1]

	Subtype	Climate	Soils	Understory	Acreage	
					Arizona	New Mexico
					Acres	
1.	Utah juniper-pinyon-sagebrush	Cold or warm, dry summer	Sandstones in cooler areas; limestone, basalt or granite in warmer areas	Indian ricegrass	6,636,000	3,082,000
2.	Utah juniper-pinyon-sagebrush-muttongrass	Cool, moist	Kaibab limestone, basalt	Cliffrose, muttongrass		
3.	Utah juniper-pinyon-alligator juniper-chaparral	Warm, moist	Sandstones, redwall limestone, granite, basalt	Sideoats grama, squirreltail, western wheatgrass, black dropseed, Junegrass	5,006,000	0
4.	One-seed juniper-pinyon-blue grama	Cool, dry winter	Kaibab limestone, tertiary sands and gravels, basalt	Blue grama, galleta, western wheatgrass	2,258,000	1,465,000

[1]Jameson, Donald A. 1967. Productive potential of sites in the pinyon-juniper type. (Establishment and progress report on file at Rocky Mt. For. and Range Exp. Stn., Flagstaff, Ariz.)

	Percent of composition
Overstory	
Utah juniper	43.8
Pinyon	37.0
One-seed juniper	9.3
Understory	
Blue grama	42.2
Snakeweed	9.8
Big sagebrush	4.8
Galleta	4.6
Squirreltail	3.5
Black sage	2.6
Indian ricegrass	1.5
Muttongrass	1.5

In these same studies, classification of pinyon-juniper sites showed site quality was influenced mainly by soil depth, profile development, and total precipitation.

In the foothills at elevations of 6,500 to 7,500 feet near Fort Stanton in southern New Mexico, one-seed juniper is several times more abundant than pinyon (Pieper et al. 1971). Blue grama constitutes 55 to 80 percent of the understory. Herbage production during a 6-year period averaged from 612 to 1,405 pounds per acre, depending on site conditions. Production was higher on loamy sites than on hill sites.

Phytosociological studies along the eastern edge of the type in New Mexico reveal how stand composition varies with elevation and latitude (Woodin and Lindsey 1954). Pinyon increases while juniper decreases with increasing elevation (fig. 4). Pinyon and juniper

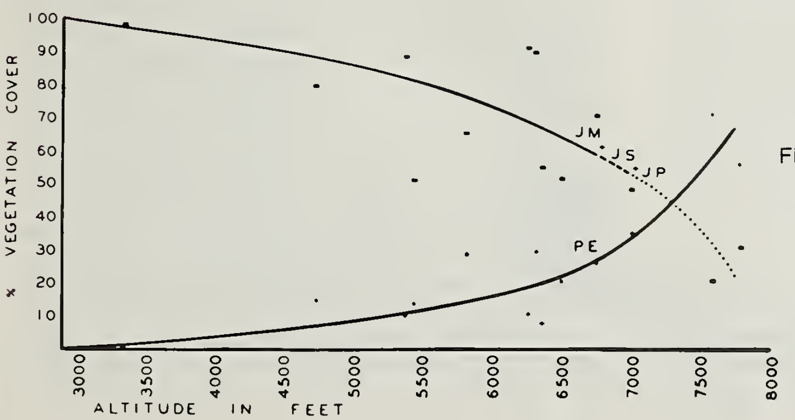

Figure 4.—Percentage of pinyon and juniper at different elevations (from Woodin and Lindsey 1954). PE = pinyon; JM = one-seed juniper; JS = Rocky Mountain juniper; JP = alligator juniper.

are about equal at 7,200 feet. The type grades into ponderosa pine at about 7,500 feet.

Three geographical subdivisions are recognized (fig. 5). In the northern subdivision, pinyon is more abundant than juniper, whereas juniper is prevalent in the other subdivisions. At a typical site in the central subdivision, one-seed juniper is about twice as abundant as pinyon. The southern subdivision includes southeastern New Mexico, where Mexican pinyon and Texas juniper are represented.

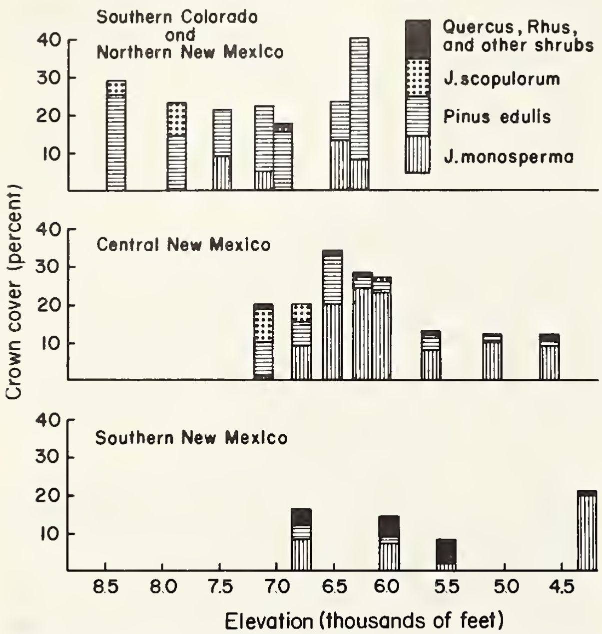

Figure 5.—Tree and shrub cover at 19 woodland sites in New Mexico and southern Colorado (adapted from Woodin and Lindsey 1954).

Pinyon-juniper occurs at elevations from 6,800 to 9,000 feet in the San Augustin Plains (Potter 1957). Pinyon makes up 60 percent of the tree overstory, alligator juniper 30 percent, and one-seed juniper only 2 percent. Gray oak comprises 6 percent of the foliar cover. The two dominants—pinyon and alligator juniper—make up 84 percent of the density, 90 percent of the foliar cover, and 89 percent of the basal area. The understory vegetation is relatively low in cover but high in number of species. Of the seven most important understory species, six are common in the grasslands of the Plains. Blue grama is most important; it alone comprises nearly half of the herbaceous cover. Ragleaf goosefoot is second and is abundant mainly under the shade of the trees. The second most abundant grass is sand dropseed.

Successional Patterns

The most notable successional trend has been the invasion of grassland communities by junipers (fig. 6). Prior to settlement of the Southwest, pinyon-juniper stands were more open and confined largely to the rocky ridges and shallow soils. With the introduction of domestic livestock, many ranges were overgrazed. Grass stands were weakened to the extent they afforded little or no competition to invading tree seedlings. Moreover, the grass was no longer thick enough to carry fire, which had periodically swept across the ranges and killed many trees. Due to the combination of overgrazing and absence of fires, trees not only encroached on the grasslands, but the original stands of trees also became more dense (Parker 1945). Another factor related to the increase in the number of trees was the dissemination of seeds by animals, including birds, coyotes, deer, and domestic livestock. Juniper seeds from animal droppings germinate faster (Johnsen 1962).

Figure 6.—Invasion of blue grama grassland by small one-seed junipers, near Ruidoso, New Mexico. Invasion of grassland communities by junipers has been a notable successional trend.

Once they become established on an area, trees usually take over as dominants. Because of their height and longevity, trees have advantages over understory plants. Trees are especially favored on coarse-textured soils.

An individual tree influences species composition and growth of understory plants far beyond its canopy. Tree roots provide more competition in the openings than under the tree crowns (Arnold 1964). The surface soil in the openings among dense stands of trees may be nearly filled with tree roots (Plummer 1958).

In general, bunchgrasses seem to be less influenced by the tree crowns than sodformers. Muttongrass and little ricegrass are commonly found under the trees, whereas blue grama grows mainly in the openings. Species such as western wheatgrass, squirreltail, and snakeweed often grow around the outside edge of tree crowns. On the Coconino National Forest, production of early-spring grasses, including muttongrass, squirreltail, prairie Junegrass, and western wheatgrass, was found to be four to five times higher under the crowns of large alligator junipers than for areas of similar size away from the trees (Clary and Morrison 1973). Moreover, grazing animals utilized green forage during the spring season almost entirely under the juniper crowns.

Responses of the herbaceous vegetation to grazing varies according to species, density of the tree stand, elevation, precipitation, soil texture and depth, and other factors. Mid-grasses, particularly sideoats grama, generally increase under protection, whereas they decrease under grazing. Grazing tends to favor short-grasses, prostrate species, and annuals at the expense of palatable shrubs and mid-grasses (fig. 7). A dense tree overstory may prevent any sizable changes in the understory. In New Mexico, during 10 to 14 years of protection from grazing, changes in the herbaceous cover were negligible where the tree canopy exceeded 30 percent, whereas density and production of desirable perennial grasses improved substantially where tree cover was less than 20 percent.[4] On the Fort Stanton range in southern New Mexico, both herbage production and height of blue grama were significantly higher after 12 years' protection from grazing (Pieper 1968). In other studies in New Mexico, total grass cover increased consistently on six representative woodland sites protected from grazing 25 years (Potter and Krenetsky 1967). Under grazing at these six sites, Junegrass decreased or disappeared while tree and forb cover increased.

[4]*Springfield, H. W. 1959. Exploratory studies relating to range conditions in the pinyon-juniper zone of the Rio Grande Basin in New Mexico. 21 p. (Unpublished report on file at Rocky Mt. For. and Range Exp. Stn., Albuquerque, N.M.)*

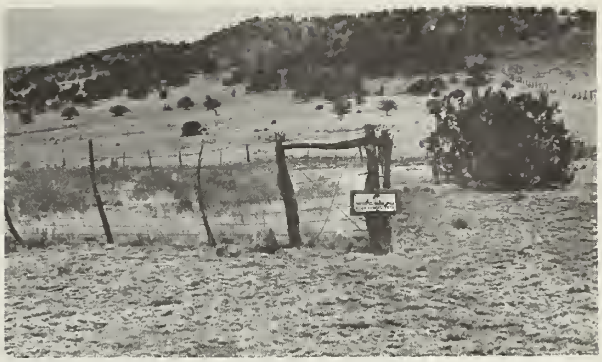

Figure 7.—On many woodland ranges, mid-grasses and palatable shrubs such as fourwing saltbush (still present within the exclosure) have practically disappeared due to continuous, yearlong, heavy grazing.

Perennial understory vegetation generally is greatest where there are few trees. The decrease in perennial grasses and forbs usually is proportional to the increase in overstory pinyons and junipers. In northern Arizona (Arnold et al. 1964), mid- and short-grasses declined sharply as tree overstory increased (fig. 8). Half-shrubs such as broom snakeweed also decreased, especially where the canopy exceeded 25 percent. The effect of tree overstory on the taller shrubs, including cliffrose and algerita, was not pronounced except where the tree canopy was more than 60 percent.

The northern Arizona studies showed an inverse relationship between tree canopy and herbage production (fig. 9). Production was about 600 pounds

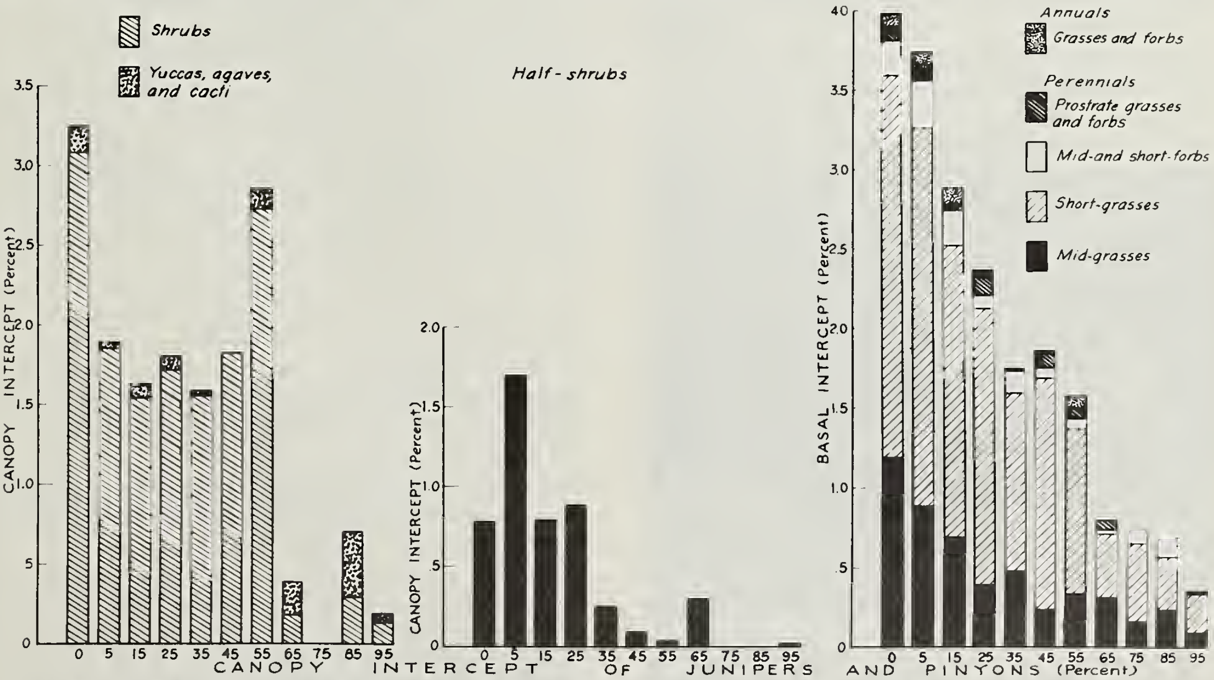

Figure 8.—Relation of understory species to canopy intercept of juniper and pinyon trees in northern Arizona (from Arnold et al. 1964).

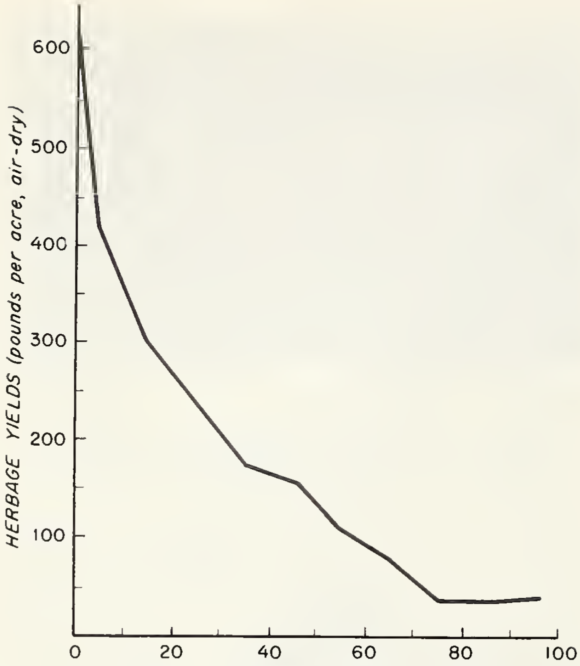

Figure 9.—Relation of air-dry herbage yield to percent canopy intercept of overstory pinyon and juniper in northern Arizona (from Arnold et al. 1964).

per acre with no trees, 300 pounds per acre with 20 percent tree canopy, and less than 50 pounds per acre with an 80 percent canopy.

Tree overstory was categorized in three patterns near Flagstaff: (1) single trees, (2) groups of two or more about the same size, and (3) small trees growing as an understory to larger trees (Jameson 1965a). The large trees apparently were more important as shade for tree seedlings than as a seed source.

Understory vegetation is commonly suppressed by juniper trees, particularly on heavy clay soils (fig. 10).

Figure 10.—Dense young stands of Utah juniper that became established about 1900. Trees so dominate the site that understory grasses occur only in isolated patches (from Arnold et al. 1964).

Juniper trees will intercept as much as 40 percent of the precipitation that falls on the crown (Skau 1964a) and up to 80 percent of the direct sunlight (Jameson 1966c). Tree litter and tree root competition, however, appear to be the main factors involved in the reduction of blue grama stands by juniper (Jameson 1966c, 1970). A foliage extract of Utah juniper significantly decreased the germination of blue grama and sideoats grama (Lavin et al. 1968). Half-shrubs such as broom snakeweed and Cooper actinea also were found to suppress blue grama (Jameson 1966a). These two shrubs did not suppress the growth of squirreltail; neither did squirreltail appear to compete against blue grama.

Fire is a natural ecological factor that slows the invasion of junipers and pinyons, and converts old tree stands to grassland (Leopold 1924, Humphrey 1950). Studies by Arnold et al. (1964) indicate successional recovery after fire in dense stands of pinyon-juniper begins with the establishment of annuals (fig. 11). The annual stage peaks in the second and third

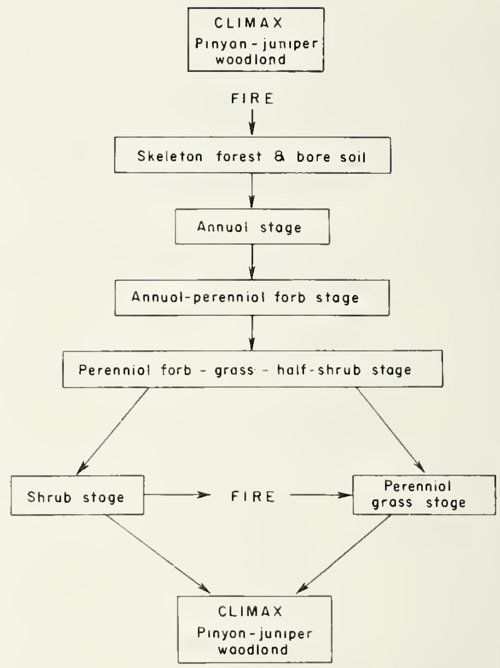

Figure 11.—Possible stages of succession after a fire in northern Arizona (from Arnold et al. 1964).

years. Perennials are more abundant than annuals by the fourth year. Half-shrubs become important the fourth year and continue to increase into the sixth year. From this point, successional recovery takes one of two courses. A perennial shrub stage likely will develop if shrubs such as sagebrush or rabbitbrush are present. Without shrubs, perennial forb-grass may be converted to grassland by second fire. When protected from recurring fires, both the shrub and perennial grass stages will be replaced eventually by climax pinyon-juniper. This successional timetable does not apply to Springerville soils (Warren P. Clary, personal communication).

Fire killed all juniper trees less than 4 feet tall on the Fort Stanton range (Dwyer and Pieper 1967). Altogether, about 24 percent of the junipers and 13.5 percent of the pinyons were killed. Production of blue grama was reduced by 30 percent the year of the fire, but recovery was complete by the next year. Species composition of the herbaceous understory was not affected, although litter was significantly less on burned areas for 3 years after the fire.

Social and Economic Characteristics

Historical Development

The pinyon-juniper type has been used by man for probably 20,000 years; it first served the Indians, then the Spanish, who founded their first settlements in and near the woodland four centuries ago (Randles 1949). Explorations have revealed that many of the early Indian habitations were in the woodland, because of the agreeable climate, plentiful supply of wood for cooking, heating, and building, berries and nuts for food, and perhaps because it was a habitat for turkey, deer, and other wild animals.

The Spanish followed essentially the same pattern of use. Besides depending on junipers and pinyons for fuel and building material, they used the trees for posts in fencing their livestock. Rural Southwesterners always have had a high opinion of the pinyon-juniper type; the pinyon is their traditional Christmas tree, pinyon and juniper foliage is used for decorations on special occasions, and the wood has been everyone's favorite. Burros loaded with packs of wood remained a familiar sight until recently.

As the population of the two States increased during the last 100 years, greater demands were made on the type for more juniper posts to use in fencing domestic animals, and more fuelwood to meet the needs of urban as well as rural people.

Throughout the past 400 years livestock have been grazed, mostly yearlong on an extensive basis. The original Spanish land grants included large blocks of land conducive to extensive management. During recent times, land ownership has become more diverse. This, together with fencing, water development, and homesteading, has resulted in more intensive management of woodland ranges.

Current Situation

Pinyon-juniper ranges continue to be used as in the past, except that demands on the resources have intensified. Grazing still is an important use, and the type remains valuable as wildlife habitat. But these important uses must now be balanced against many others. The type, for example, is receiving much heavier recreational use than formerly.

More and more people are discovering pinyon-juniper woodlands as a desirable place to live. Real pressures are being put on the type by land developers. Roads are being carved through the wooded hills with little regard for plants and soils. Subdivisions are springing up throughout the type.

Changing the use from grazing or wildlife habitat to home or recreational sites is having serious impacts on the land resources and domestic and wild animals. Much former rangeland no longer is available for grazing. Moreover, wildlife food and cover are lost as roads and homes are built. The trend, however, is practically irreversible.

Ranching Operations

Most ranches that use pinyon-juniper ranges are cow-calf outfits. A few ranches have switched largely to yearlings, which often are grazed on leased lands. Not many woodland ranges are grazed by sheep, and goats are nearly nonexistent.

Grazing usually is yearlong unless ranchers have grazing permits, which are seasonal. Many ranchers are practicing rotation or deferred grazing. A few ranchers have irrigated or special nonirrigated pastures, but most depend almost entirely on native range forage.

Supplemental feeding is a common practice. Ranchers supply protein concentrate blocks or cottonseed meal during the winter, or during drought periods.

Herefords are the most popular breed, but there are also Angus, Brangus, and Charolais cattle. Crossbreeding is becoming more popular. Mexican cattle are common on yearling ranches.

Calves and yearlings are the principal source of income. Most calves are dropped in the spring and marketed in the fall, mainly to feedlots.

Seasonal breeding is practiced. Bulls are placed in service as 2-year-olds. They usually are fed supplements prior to being placed in the breeding herd during the summer.

In the central mountainous region of New Mexico, Gray (1970a) reported 32 percent of the grazing use for small (98 head) cow-calf ranches was supplied by USDI Bureau of Land Management (BLM), and USDA Forest Service permits. Only 22 percent of the total grazing use for medium-sized (283 head) ranches was supplied by these two agencies. Investments for a small cattle ranch in central and northwestern New Mexico totaled $120,000 in 1965, compared with $278,000 for a medium-sized ranch. Land organization and investment per ranch in 1965 in small- and medium-sized cow-calf ranches in the central and northwestern mountains of New Mexico (adapted from Gray 1970a, 1970b) were:

	Ranch size	
	Small	Medium
LAND USE		
Rangeland (*acres*)		
Owned	1,720	6,000
Private lease	720	840
State lease	0	640
Total	2,440	7,480
Federal grazing permits (*animal unit months, AUM*)		
Bureau of Land Management	510	520
Forest Service	60	470
Total	570	990
INVESTMENT (*dollars*)		
Owned land	64,000	176,000
Grazing permit (at $25/AUM)	14,000	25,000
Improvements	20,000	29,000
Machinery, equipment	6,000	8,000
Livestock	16,000	40,000
Total	120,000	278,000

Grazing Use

Kind of Animals

Many more cattle than sheep graze pinyon-juniper ranges in the Southwest. Sheep numbers have declined drastically since World War II. Permitted livestock use in 1972 on the woodland ranges of the National Forests in the Southwestern Region of USDA Forest Service was as follows:

	Animals	Grazing use
	(*Number*)	(*AUM*)
Cattle	54,700	630,000
Sheep	15,100	140,000

Few examples can be found of common or dual use of woodland ranges by cattle and sheep. There appear to be opportunities, however, for common use as a means of improving efficiency of forage utilization, particularly on ranges that support a high proportion of forbs and half-shrubs.

Carrying Capacity

Capacities vary considerably, depending on density of the tree overstory, topography, condition of the understory, and many other factors (fig. 12). Range condition, as an expression of "state of health" of the range, usually provides clues as to the number of animals an area will support. Based on an analysis of National Forest Allotments where pinyon-juniper comprises at least 67 percent of the total plant cover, range conditions in 1972 were as follows:

Figure 12.—Grazing capacities of woodland like this in northern New Mexico are low because of the relatively rough topography, shallow soil, sparseness of forage, and scarcity of water for livestock.

Range condition	Area	Grazing capacity
	(*Percent*)	(*Acres/AUM*)
Very poor	5.1	28.2
Poor	40.7	11.8
Fair	46.1	6.6
Good	8.1	3.9

These figures suggest that over 90 percent of the woodland ranges are in poor or fair condition, and that less than 10 percent are in good condition. Pinyon-juniper ranges generally are in better condition on the Coronado, Lincoln, and Tonto National Forests than on the others (table 2).

About twice as many acres are required to support a cow for 1 month on woodland range in poor condition as in fair condition (table 2). Differences in grazing capacities reflect not only differences in range conditions, but also fairly large differences in the plant communities themselves and in environmental conditions from one part of the Southwest to another (figs. 13, 14). For example, the grazing capacity of poor-condition woodland range varies from 16.9 acres/AUM on the Kaibab National Forest to 6.1 acres/AUM on the Lincoln.

Seasons of Grazing

Most pinyon-juniper ranges in Arizona and New Mexico are grazed yearlong, especially lands in private ownership. Because of the generally mild winters and relatively cool summers, the woodland type is well suited to yearlong use. But from the standpoint of conserving the plant and soil resources, some form of seasonal use—in conjunction with deferred grazing—usually is desirable.

About half of the total woodland acreage on National Forest Allotments in the Southwestern Region is grazed yearlong (table 3). About a fifth of the pinyon-juniper woodland is grazed only during summer (May 1 to October 31), or only in the winter (November 1 to April 30). The remaining woodland range is grazed either in the spring or fall, or both.

Table 2.--Range-condition class and estimated grazing capacities on pinyon-juniper ranges on southwestern National Forests

National Forest	Range condition class[1]							
	Very poor		Poor		Fair		Good	
	Percent	*Acres/AUM*	*Percent*	*Acres/AUM*	*Percent*	*Acres/AUM*	*Percent*	*Acres/AUM*
Apache[2]	6	--	42	9.5	42	5.4	10	4.5
Carson	25	19.5	66	14.6	9	--	0	--
Cibola	4	23.6	43	11.1	48	5.5	5	--
Coconino	8	29.2	60	10.8	31	9.0	1	--
Coronado	0	--	9	10.9	71	3.8	20	3.0
Gila	4	--	34	10.2	55	8.1	6	3.9
Kaibab	7	43.8	72	16.9	21	5.9	0	--
Lincoln	1	--	26	6.1	52	5.8	21	4.1
Prescott	3	--	66	9.5	30	5.5	1	--
Sitgreaves[2]	2	--	36	15.0	62	11.3	0	--
Tonto	0	25.0	12	15.0	71	5.9	17	4.1
Santa Fe	1	--	24	--	61	--	14	--

[1]For National Forest Allotments with at least 67 percent pinyon-juniper.
[2]These two Forests were combined subsequent to this statistical summary.

Figure 13.—This very poor-condition range in a moderately dense woodland in northern New Mexico has a grazing capacity of about 20 acres per animal unit month.

Figure 14.—An example of well-managed pinyon-juniper range. The tree stand is open, and the grassland is in good condition, with a grazing capacity of about 4 acres per animal unit month.

In general, yearlong use of woodland ranges is more prevalent in the central and southern parts of the two States. For example, on 5 of the 12 National Forests in the Southwestern Region—the Apache, Gila, Lincoln, Prescott, and Tonto—90 percent or more of the woodland range is grazed yearlong. By contrast, yearlong use is negligible on the more northerly Forests, such as the Kaibab and Carson. Exclusively summer use is common on the Coconino, Sitgreaves, and Carson, whereas grazing in the winter only is practiced to some extent on the Kaibab and Santa Fe.

Grazing Systems

Continuous grazing, with little or no concern for the needs of the plants, has been the prevailing system on most woodland ranges for centuries. Only in fairly recent times have various rotation or deferred systems of grazing been adopted. Through the efforts of the conservation agencies, increasingly larger acreages of private as well as public land are being brought under more intensive grazing management. Both the Forest Service and Bureau of Land Management have made substantial progress toward institut-

Table 3.--Season of use for the pinyon-juniper allotments on the National Forests of Arizona and New Mexico

National Forests	Percent of total pinyon-juniper acreage				Allotments with 67% or more pinyon-juniper range			
	Yearlong	May 1-Oct. 31	Nov. 1-Apr. 30	Other	Yearlong	May 1-Oct. 31	Nov. 1-Apr. 30	Other
	Percent				*Number*			
Apache	94	5	1	0	88	4	8	0
Carson[1]	0	88	0	12	0	67	0	33
Cibola	68	10	18	4	52	16	27	5
Coconino	19	41	39	1	17	29	50	4
Coronado	65	0	34	1	61	0	37	2
Gila	91	2	6	1	80	3	14	3
Kaibab	6	34	60	0	10	30	60	0
Lincoln	93	3	4	0	84	6	9	1
Prescott	93	0	7	0	81	0	19	0
Sitgreaves	32	53	15	0	15	70	15	0
Tonto	98	0	0	2	95	0	0	5
Santa Fe[1]	4	8	72	16	14	29	43	14

[1]Incomplete data.

ing grazing systems on woodland ranges under their administration.

More than half of the National Forest woodland ranges now are under some form of deferred or deferred-rotation grazing (table 4). Of several grazing systems recognized, the most commonly used on woodland ranges in Arizona and New Mexico is rest-rotation. With this system, grazing is deferred on various parts of a range in successive years, allowing the deferred part complete rest for 1 year. Two or more units are required. Also in fairly common use are deferred grazing and deferred-rotation grazing. Straight rotation grazing, utilizing two or more pastures, is practiced on about 12 percent of the National Forest woodland.

Improving Forage Production

Seeding

For successful seeding in the pinyon-juniper type, control of the tree overstory usually is necessary. The range may be seeded during the actual tree control operations, particularly in conjunction with chaining. Seeds usually are broadcast with a mechanized seeder and covered with a harrow, chain, or similar equipment. On large-scale projects where trees are double chained, seeds commonly are aerially broadcast between the first and second chaining. Another common practice is to distribute seeds in the pits and disturbed soil where trees have been dozed.

Table 4.--Grazing systems used on pinyon-juniper ranges on the National Forests of Arizona and New Mexico (percent of total pinyon-juniper acreage)

National Forests	Percent of total pinyon-juniper acreage used for each grazing system									
	Continuous	Once over	Rotation (No. pastures) Two	Three	Four or more	Deferred	Rest-rotation	Deferred-rotation	Rotational deferment	Other
	Percent									
Apache	30	0	1	0	0	53	14	2	0	0
Cibola	6	0	5	6	0	1	17	8	7	50
Coconino	15	0	5	0	0	20	23	26	0	11
Coronado	21	0	4	4	7	17	2	24	5	16
Gila	23	0	1	1	1	5	39	21	6	3
Kaibab	24	0	0	0	0	17	49	0	10	0
Lincoln	26	0	3	2	0	5	23	40	0	1
Prescott	25	0	2	0	0	55	1	1	0	16
Sitgreaves	8	0	1	23	29	0	39	0	0	0
Tonto	15	0	0	0	0	8	8	66	0	3
Average	19	0	2	4	4	18	22	19	2	10

Seeds can be distributed and planted with a drill only where the land has been cleared of debris left during the control operations. In some areas, undesirable understory vegetation must be eliminated before drilling. Plowing has been the most effective seedbed preparation method. On plowed seedbeds, the best method of seeding is conventional drilling, using double-disk furrow openings with depth bands. On nontilled seedbeds, furrow drilling—with furrows more than 12 inches wide and deeper than 2 inches—can be expected to give better seedling establishment than conventional drilling (Lavin et al. 1973).

Crested wheatgrass can be successfully seeded in northern New Mexico and Arizona, especially where big sagebrush is the principal understory species (fig. 15). Weeping lovegrass appears well adapted in eastern and central Arizona in areas below the Mogollon Rim where summer rainfall is high and winter temperatures mild. Other species that appear widely adapted in the pinyon-juniper include western wheatgrass, Russian wildrye, sideoats and blue gramas, sand dropseed, spike muhly, yellow or Turkestan bluestem, sweetclover, and fourwing saltbush (table 5). Yellow bluestem and Russian wildrye appear to fit situations where winter precipitation is insufficient for crested wheatgrass. Blue grama, especially the Lovington variety, is adapted to most areas in the woodland type.

Figure 15.—Crested wheatgrass is suitable for seeding pinyon-juniper ranges characterized by cold, wet winters.

Soil moisture probably is the main consideration in seeding pinyon-juniper ranges. Cultural practices that concentrate and conserve moisture usually are the most effective. Methods that provide or maintain a

Table 5.--Species adapted for seeding woodland ranges in the Southwest, according to winter climate (adapted from Springfield 1965, USDA-FS 1970, and Lavin's studies as reported by Renney 1972)

Species	Soil	Winter climate and precipitation (inches)				Annual precipitation (inches)		
		Cold		Warm				
		Dry (4-6)	Wet (7-9)	Dry (4-7)	Wet (7-9)	<14	14-16	>16
Wheatgrass, western	Loam, clay	x	x	x	x		x	x
pubescent	Loam, clay		x				x	x
crested	Loam		x			x	x	
intermediate	Loam, clay		x					x
Wildrye, Russian	Loam, clay	x	x	x		x	x	
Grama, blue	Sandy, loam	x	x	x		x	x	x
black	Sandy, loam			x	x	x	x	
sideoats	Sandy, loam	x	x	x	x	x	x	x
Lovegrass, Boer	Sandy, loam			x	x		x	x
Lehmann	Sandy, loam			x	x	x		
weeping	Sandy, loam			x	x		x	x
Dropseed, sand	Sandy, loam	x	x	x	x	x	x	
Muhly, spike	Loam, clay	x	x	x	x		x	x
Bluestem, Turkestan (yellow)	Sandy, loam	x	x	x	x		x	x
Ricegrass, Indian	Sandy, loam	x	x			x	x	x
Sweetclover	Sandy, loam, clay	x	x	x	x	x	x	x
Alfalfa	Loam	x	x				x	x
Burnet	Loam	x	x	x	x		x	x
Saltbush, fourwing	Sandy, loam, clay	x	x	x	x	x	x	x

mulch on the soil surface generally result in better seedling establishment of desirable shrubs as well as grasses. Several mulches have proved effective, including tree branches, dead grasses or forbs, straw, plastic film, petroleum resin, and asphalt. Brush mulch was found beneficial not only in establishment but also in the maintenance of several seeded species on woodland ranges in central Arizona (Judd 1966). A special form of mulching consists of killing the competing vegetation in place with herbicides (Gomm and Lavin 1968). Black plastic mulch improved establishment of cercocarpus at a woodland site near Santa Fe, New Mexico (Springfield 1972).

Tree Control

Although snakeweed, rabbitbrush, pingue, and other noxious plants are common on Southwestern woodland ranges, the main concern is with control of the trees themselves. Most studies have shown that as tree overstory increases, forage decreases. Large-scale efforts have been undertaken to convert woodland to grassland. Control methods may be classified as (1) mechanical, (2) chemical, and (3) burning.

Mechanical.—Control of pinyon-juniper dates back to when the trees were felled with axes to make room for crops. Individual farmers and ranchers also cut trees to open up their pastures for more grazing. Most of these efforts were small scale. Relatively large-scale removal of pinyon-juniper on private land began about 30 years ago. The acreage controlled annually increased to 164,000 acres in 1959 (Cotner 1963), most of it by cabling, the least expensive method. For several reasons the trend reversed in the 1960's; fewer acres were cabled, and more acreage was treated by other methods.

Evidence from the Fort Apache Indian Reservation dramatized the potential advantages from controlling pinyon-juniper. By 1954, 80,000 acres of the Reservation had been cleared. The benefits from clearing were readily apparent. Under dense stands of trees herbage production was less than 100 pounds per acre, whereas after clearing production increased to more than 600 pounds (Arnold and Schroeder 1955). The increase in production was gradual; 350 pounds per acre 3 years after control, 500 pounds in 5 years, and 650 pounds in 10 years.

Not all pinyon-juniper control in Arizona and New Mexico has been that successful, however.

Cabling, the most popular method for several years, fell into disfavor because it proved ineffective on many areas (fig. 16). The method is suitable to even-aged stands of trees 15 to 25 feet tall on shallow, limestone sites. In a mixed stand where half of the trees were less than 6 feet tall and the soil was clay, however, cabling killed only 43 percent of the trees (Cotner 1963). Moreover, the trees that survived cabling often were stimulated to grow two to three times faster due to release from dominance by the taller trees. The tree stands thus ended up more dense than the original.

Chaining generally is more effective and is more frequently used than cabling. Single chaining kills most of the older, larger trees, but leaves the young trees. Double chaining, usually in the opposite direction, increases the percentage of killed trees. For example, Aro (1971) reported the following averages for sites with 180 pinyons and 160 junipers per acre:

	Tree kill (*Percent*)
Single chaining	38
Double chaining	60

Single chaining killed 61 percent of the trees where half or more of the trees were taller than 10 feet, but only 30 percent of the trees where more than half were shorter than 10 feet.

Chaining that kills a high percentage of old trees but leaves many young ones can create an ecological situation more difficult and expensive to treat than the original (Aro 1971).

Besides the many small trees not killed, another disadvantage of chaining is the large amount of debris left on the ground. The amount varies with size and density of the trees, and with the method of control. Daniel et al. (1966) related the control method to the tree kill and slash cover as follows:

	Tree kill	Slash cover
	(*Percent*)	
Cabled	57	19
Chained one way	70	10
Chained two ways	83	13
Burned	96	6

The tree crown debris interferes with forage utilization and livestock movements. This is not a permanent loss, however. As the dead crowns deteriorate they gradually allow much of the forage to become available in 5 to 10 years.

Burning and other followup treatments have been used to remove excess slash and, at the same time, kill many of the young trees left alive. The burning should be done after the needles dry but before they drop.

The recommendation is to use cabling or chaining on medium-dense, mature stands on fairly smooth terrain. Optimum cost/benefit ratios are achieved where there is 3 to 11 percent tree cover. Neither chaining nor cabling effectively kills trees less than 10 feet tall.

A high proportion of the trees must be large for chaining or cabling to be effective. Small pinyons and junipers less than 3 inches in diameter (1 foot above the ground) rarely are knocked down by chaining. Trees in the 3- to 5-inch diameter class usually are

Figure 16.—Cabling proved ineffective on many areas. Prior to cabling, this area supported a mixture of large and small trees **(top)**. Cabling missed many small trees **(bottom)**, which will be stimulated to grow faster and will eventually dominate the area.

knocked down but may not die. Pinyon appears more likely to die after being pushed over than juniper. Junipers, even those 6 to 9 inches in diameter, may survive unless the root system is severely injured. Daniel et al. (1966) determined the percentage of the stand that would have to be greater than 7 inches in diameter to achieve acceptable tree kill at 75 percent and 95 percent as follows:

	Tree kill of —	
	75%	95%
Cabling	85	100
Chained one way	60	85
Chained two ways	45	78

A combination method involves chaining followed by windrowing. The windrowing consists of scraping the downed trees, together with some soil, into long ridges. This operation not only removes most of the young trees missed by the chain, but it also eliminates many undesirable plants such as snakeweed. After windrowing, some form of revegetation ordinarily is required. Drilling is preferable to broadcast seeding. According to Aro (1971), the chaining-windrowing technique is the most effective mechanical method of replacing trees with grass. Daniel et al. (1966) indicate that criteria include slopes not exceeding 15 percent, and soils at least 2 feet deep with a sandy or silt loam surface. They also state that site characteristics that indicate high productivity from seeded grasses in the 15- to 16-inch precipitation zone are (1) the tree canopy prior to treatment is 36 percent; (2) pinyons are 30 feet tall, or junipers are 22 feet tall; and (3) total soil depth is 30 inches, with a 6-inch A-horizon of sandy loam texture and 5-percent stoniness.

As Aro (1971) points out, ecological criteria restrict the chaining-windrowing method to certain sites that will usually produce greater benefits when converted to grassland than if left untreated. Stony, wooded ridges and canyon slopes, which are better suited to trees and browse, will be left intact as wildlife habitat.

Pushing and uprooting individual trees with a bulldozer is a good method in light or medium-dense stands of pinyon-juniper. A variety of equipment is available, including the conventional straight blade, or modifications such as the Huladozer, stinger, or pusher bar. An advantage of this method is that certain trees can be left for shade or esthetics. The method works best when there is adequate soil moisture, but not when the ground is frozen or too wet. Because of the large amount of forage covered by downed trees, followup stacking or windrowing—and possibly burning—is desirable. Broadcasting seed in pits left by the trees and on other disturbed areas also is desirable. Bulldozing is recommended in mixed-age stands up to 100 trees per acre, or when the tree cover is 3 to 11 percent.

Hand chopping, sawing, or grubbing is practical for scattered trees on small areas, or as a cleanup method. This is the most thorough of all mechanical methods, but the labor costs are high. Removal of wood products such as posts, firewood, and Christmas trees may help offset the costs.

Tree crushing is one of the most effective methods for controlling dense stands of pinyon-juniper. The tree crusher moves through the trees like a giant brush cutter (fig. 17A), pushing them out of the ground, cutting them up into fireplace-sized pieces (fig. 17B), and creating openings for livestock and wildlife (Lamb 1970). The method is especially well suited for sizable areas with a remnant stand of grasses and forbs that will respond to removal of tree competition, and to areas where esthetics are important (Williamson and Currier 1971). It is limited to relatively nonstony soils and to slopes of less than 15 percent.

Chemical.—Tree-killing chemicals have not been widely used for controlling pinyon-juniper because the trees are somewhat resistant to most herbicide treatments. According to Johnsen (1967), more is known about control of juniper than of pinyon. Effective herbicides applied to the foliage and stems of juniper include: arsenite, AMS (ammonium sulfamate), esters of 2,4-D and 2,4,5-T, and PBA (polychlorobenzoic acid). To control individual junipers by foliage treatment requires thorough coverage. Rates of 8 to 16 pounds of acid equivalent per hundred gallons of spray are needed with these chemicals.

Herbicides that are effective when applied to the soil surface around the base of the juniper tree include pelleted fenuron and granular TBA (tri-

Figure 17.—The 83-ton tree crusher **(top)** uproots and crushes the trees in one operation. Pieces of trees left on the ground **(left)** are the right size for fireplaces.

chlorobenzoic acid). These two chemicals have been effective when applied to the tree base at about 1 tablespoon of material per 3 feet of tree height, for trees up to 12 feet tall. Higher rates are needed on fine-textured soils. Picloram is effective when applied to the foliage at 1 pound acid equivalent per hundred gallons as a wetting spray, or at 7.5 pounds active ingredient per acre as pellets.

Information concerning the effects of herbicides on pinyons is scarce (Johnsen 1967). Pines generally are resistant to foliage sprays of 2,4-D, 2,4,5-T, and PBA. AMS, however, has been effective as a foliage spray or as a frill treatment (Herman 1954). Pelleted fenuron applied to the tree base at the rate of 1 tablespoon per 3 feet of height has killed pinyon on loam soils, and picloram seems effective as either a foliage or soil treatment (Johnsen 1967).

Burning.—Burning ordinarily does not afford a high degree of site selection but it can be effective. Arnold et al. (1964) consider four situations where burning is useful in the pinyon-juniper: (1) broadcast burning, (2) burning individual trees, (3) burning grassland areas, and (4) burning slash.

Broadcast burning of mature stands of pinyon-juniper requires special conditions. The stands must be dense and the burning must be done during hot, dry, windy weather. It is a hazardous operation; the risk of escape is high. But there are a number of examples of the effectiveness of prescribed burning, especially on the Hualapai Indian Reservation. From 1955 through 1963, the Hualapai Indians burned and seeded 17,000 acres of pinyon-juniper at a cost of $4.50 per acre. Forage production was increased about 500 pounds per acre.

Burning individual trees is best suited to open stands, especially small trees of one-seed or Utah junipers (Jameson 1966b). The method is not appropriate for trees more than 10 feet tall, nor for sprouting species. Large trees require too much time, making the cost prohibitive. Small trees, however, are quickly burned. Jameson (1966b) reports a stand of 100 trees 10 feet tall would take two men a total of about 35 minutes. Either propane or oil-burning torches are suitable (fig. 18). Leaf scorch is the most useful indicator of mortality. For 100 percent kill of juniper, 60 percent of the crown should be scorched. An advantage of the method is that individual trees can be burned at any season.

Burning of grassland communities to control invading junipers and pinyons has been tried on a limited scale. Grazing must be deferred for a growing season so that enough fuel accumulates to carry the fire. Protection from grazing also is desirable for a growing season following the burn. Based on studies of lethal temperatures, Jameson (1961) concluded grasses such as the gramas and galleta were likely to be damaged by fires during the summer months; therefore he suggested prescribed burning when the

Figure 18.—Gas burner being used to kill a juniper (from Arnold et al. 1964).

air is cooler and more humid. In later studies on galleta-black grama range, however, he found that, 2 years after fires in January, March, and June, grass production and cover were essentially the same as prior to burning (Jameson 1962). He reported 70 to 100 percent of the one-seed junipers less than 4 feet tall were killed by fire, compared with only 30 to 100 percent of the trees 5 to 6 feet tall.

Guidelines.—Guidelines for pinyon-juniper control are available. The New Mexico Inter-Agency Range Committee (1968) recommends limiting treatment to stands on soils 18 inches or more deep when the objective is to increase grass production.

The Arizona Interagency Range Technical Sub-Committee (1969) recommends chaining or cabling for stands of mature trees in excess of 100 trees per acre. They suggest broadcast burning of dense stands where pinyon is a component. Individual tree burning is recommended on stands of young trees up to 100 trees per acre. Bulldozing is recommended in mixed-age stands up to 100 trees per acre.

The USDA Forest Service Region Three Non-structural Range Improvements Handbook (1970) briefly describes and points out the limitations of several control methods (table 6). Recommendations call for treating slopes of 20 percent or less, leaving some northeast exposures untreated for wildlife, and designing treatment boundaries to blend into the landscape. Treatment areas should be of a size and shape beneficial to wildlife. If islands of trees are left, they should be long and slender, and at least 10 acres in size. Width of openings should not exceed ¼ to ½ mile.

Plant response to tree control.—Response of the understory vegetation to removal of tree competition varies according to soil and climatic characteristics, species composition, and density of the understory and other factors. In northern Arizona, removal of

Table 6.--Methods of pinyon-juniper control (extracted from Nonstructural Range Improvements Handbook prepared by Southwestern Region, R-3, USDA-FS 1970)

Method and type of equipment	Time	Limited to	Remarks
TREE CRUSHING Modified tree crusher.	Use when ground is not frozen or when excessive moisture is not present.	Large acreages of non-stony soils on slopes of less than 15 percent. Optimum benefit-cost ratio in very dense stands.	Gives good results with high esthetic values.
BURNING Propane torches; fire control equipment.	Spring or summer.	Light infestations of small trees for individual tree burning. Optimum benefit-cost ratio with light stands.	Gives good results, and warrants wider use. May be used following chaining.
CHAINING (CABLING) Chain weighing 70 pounds or more per link.	Any time except when ground is frozen.	Large acreages of mature, even-aged trees. Optimum benefit-cost ratio with light and medium stands.	Fire for debris cleanup must be part of the treatment.
CHOPPING Brush chopper.	When seeding is needed, coincide with seeding time.	Little trees in small, odd-shaped areas.	Limited application; gives fair results. Poor results on alligator juniper.
ROTOCUTTER Highway-type mower. Heavy duty rotary mower.	Treat when least damaging to associated species.	Areas with small trees and no stones.	Gives good results. Will not kill alligator juniper. Desirable treatment for new invasion.
PUSHING (DOZING) Wheel or track-type tractor with blade or "stinger."	All year. Do not push alligator juniper when ground is frozen.	Light and medium stands.	Burning, windrowing, or stacking debris where necessary should be a planned part of the treatment.
HAND GRUBBING Grubbing hoe.	All year except when frozen.	Light and medium infestations of small trees.	Gives good results. Use as followup treatment or on new invasion.
HAND CUTTING Ax or saw.	All year.	Light infestations.	Gives good results except on alligator juniper, where it is ineffective. Wood products may return part of cost.
CHEMICAL SOIL STERILANT Fenuron-- Rate: Trees less than 6 ft high, 1 T. on light and medium soils; 2 T. on heavy soils. Double amounts for trees 6-12 ft high.	July to September.	Light stands only.	For other chemical treatment, see Section in Handbook on Chemical Control of Range Weeds.
CHEMICAL STUMP TREATMENT Ammate crystals; or 2,4-D and 2,4,5-T with diesel; or Benzae 94.	At time of cutting.	Light stands only.	Alligator juniper only.

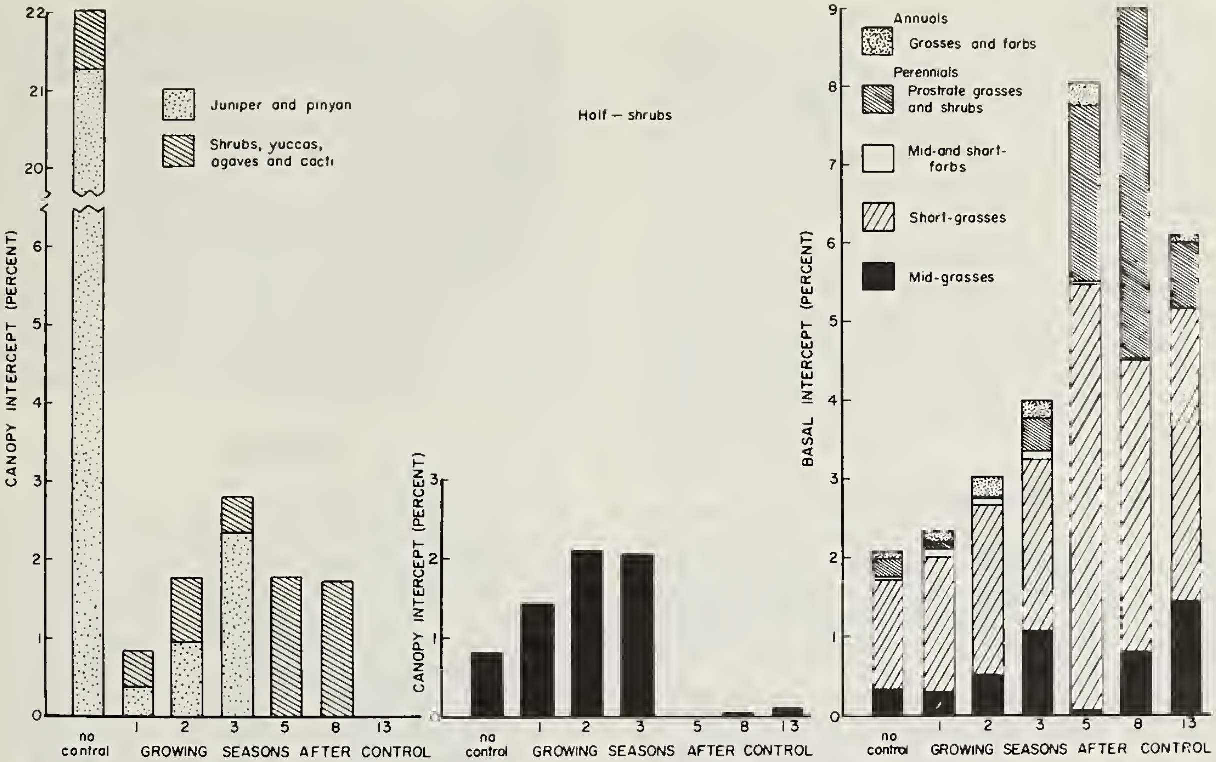

Figure 19.—Changes in plant cover of (left) woody species, (center) half-shrubs, and (right) herbaceous species following pinyon-juniper control (from Arnold et al. 1964).

the trees resulted in a marked increase in half-shrubs, primarily snakeweed (Arnold et al. 1964). Snakeweed increased steadily for two or three growing seasons, then abruptly declined (fig. 19). Mid-grasses, particularly threeawns and sideoats grama, increased with seasons after control. Western wheatgrass responded rapidly to tree removal, especially on heavy soils. Of the short-grasses, blue grama was by far the most important; it continued to increase through the fifth year after control. Annuals increased the first two growing seasons, but by the fifth season they had been largely displaced by perennials. Herbage production increased each year, reaching a maximum about the tenth year after control (fig. 20).

Understory vegetation does not always improve greatly with removal of the overstory. For example, on the Heber Ranger District of the Apache-Sitgreaves National Forest, no improvement in the understory resulted where calcium carbonate in the surface soil was about 13 percent and the tree overstory 13 to 26 percent. Perennial grass yields increased severalfold, however, where the carbonate was only 5 percent and the tree overstory 36 to 44 percent (O'Rourke and Ogden 1969). Crown cover of trees, together with calcium carbonate in the surface soil, may be useful for predicting understory response.

The advisability of controlling Utah juniper on very stony, clay Springerville soils has been questioned due to the difficulty in revegetating these soils. Ten years after tree control, some areas on Beaver Creek still grew mainly snakeweed and goldeneye; those areas that initially had little native perennial grass still were producing no more forage than

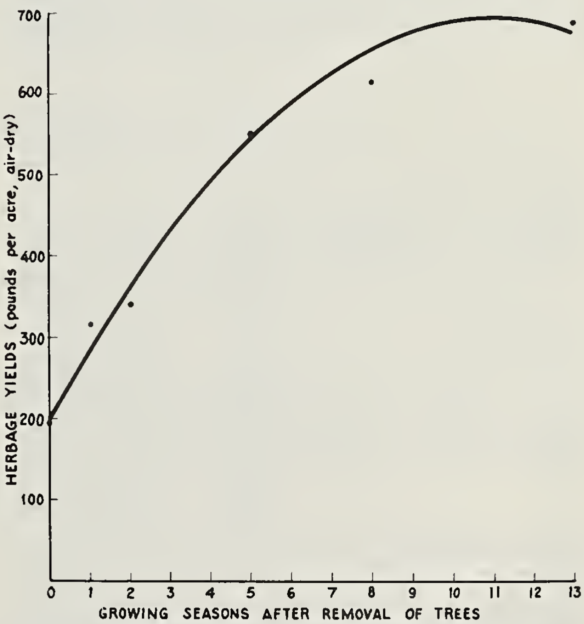

Figure 20.—Herbage yields by number of seasons after tree control (from Arnold et al. 1964).

untreated areas (Clary 1971). Where seeded grasses were successfully established, however, perennial grass yields increased rapidly, peaked in 4 to 6 years, then declined. Areas with Springerville soils can be expected to support mainly forbs and half-shrubs for years after tree removal unless considerable perennial grass is present before treatment or revegetation attempts are successful.

Costs.—Costs of pinyon-juniper control vary with density and size of the trees, topography, methods used, and acreage to be treated. Some of the early cost figures, particularly costs for hand chopping on Indian lands, no longer appear valid. Likewise, costs for tree crushing appear somewhat conservative. Nevertheless, sufficient cost information is available for comparisons.

Cabling and chaining generally are the least expensive methods. One of the most expensive, based on published data, is clearing alligator juniper with chain saws (Miller 1971); costs for felling the trees, piling the slash, and spraying the stumps totaled $45 per acre. Barger and Ffolliott (1972) show cabling or chaining a heavy stand of mature trees costs $5 to $6 per acre (table 7).

According to the New Mexico Inter-Agency Range Committee (1968) costs per acre were as follows:

	Cost/acre
Tree crusher	$7.50 to 10.00
Pushing or dozing	5.00 to 7.00
Chemical	4.50
Hand cutting	Up to 6.00
Chaining (one-way)	3.50
Individual tree burning	1.75 to 1.90

Costs for tree crushing in 1975 ranged from $15 to $25 per acre. Likewise, costs of the other practices have increased substantially. As examples, Clary et al. (1974), using 1972 conditions, estimate $9 and $13 per acre as the cost for pushing and piling a stand of 125 trees per acre. Followup cleaning and slash burning costs vary from $2 to $4 per acre, and seeding costs are estimated at $4.20 per acre. Total cost for juniper conversion in an operational-sized project would then be about $19.69 per acre in 1972 (Clary et al. 1974).

An analysis of the economic aspects of pinyon-juniper control on medium-sized ranches in New Mexico (Gray et al. 1965) shows the following per-acre job costs in 1961:

Practice 1	
Pushing trees	$14.00
Seedbed preparation	.98
Drilling seed	2.66
Deferred grazing	.50
Fencing	5.48
	$23.52
Practice 2	
Chaining (one way)	$4.00
Aerial seeding	2.63
Deferred grazing	.50
Fencing	5.48
	$12.61

Over a 10-year period, only 3 percent of net income of the ranch would be required to meet the annual payment for chaining 267 acres of pinyon-juniper (table 8). If the tree stands are not too heavy, the costs per acre for controlling them are relatively modest,

Table 7.--Costs per acre of control treatments in southwestern pinyon-juniper stands by stand size and density (adapted from Barger and Ffolliott 1972)

Operation and method	Stand	Density	Cost per acre	Source
			Dollars	
Tree clearing:				
Cabling or chaining	Mature	Heavy	5.00- 6.00	Worley and Miller (1964)
	Mature	Medium	Average 3.50	N.M. Inter-Agency Range Comm. (1968)
	Mature	Light-medium	1.22- 2.33	Cotner (1963)[1]
	Small	Light-medium	.95- 1.46	Cotner (1963)[1]
Pushing	Mature	Heavy	8.00-14.00	Worley and Miller (1964)
	Mature	Light-medium	5.00- 7.00	N.M. Inter-Agency Range Comm. (1968)
	Mature	Light-medium	3.72-10.90	Cotner (1963)[1]
	Small	Light-medium	3.13- 7.66	Cotner (1963)[1]
Hand cutting, piling	Mature	Heavy	45.00-55.00	Worley and Miller (1964)
	Mature	Heavy	Average 45.02	Miller (1971)
	Small	Light	Average 6.00	N.M. Inter-Agency Range Comm. (1968)
Cleanup following pushing and cabling			2.00- 6.00	Worley and Miller (1964)
			Average 6.00	N.M. Inter-Agency Range Comm. (1968)
Slash burning			.50- 1.00	Worley and Miller (1964)

[1]Predicted costs, based on analysis of experienced costs.

Table 8.--Proportion of net income of a medium-sized ranch (245 animal units) required to pay for controlling trees (Gray et al. 1965)

Control method	Size	Total cost	Percent of net income required to meet annual payments		
			5 yr	10 yr	15 yr
	Acres	*Dollars*		- - *Percent* - -	
Handcutting	1,144	2,357	8	5	4
Dozing	267	3,738	20	11	8
Chaining	267	1,068	6	3	3

but when the stands are dense, the costs per acre may be excessive. Few ranchers can afford to control heavy stands on large portions of their ranches without financial help. According to Gray et al. (1965), ranchers could receive the following payments under the Agricultural Conservation Program: pinyon-juniper control, 66 percent of total cost; reseeding, 50 percent of cost; and fencing, 44 percent of cost.

The benefits are rather difficult to assess, but Cotner and Kelso (1963) calculated that reduced labor and increased beef sales resulting from juniper control were worth $1.19 to $3.89 per acre to ranchers in 1963. On one allotment on the Prescott National Forest, bulldozing 7,100 acres of juniper at a cost of $8,412 allowed an increase in cattle from 4,480 animal units before treatment to 7,500 animal units after treatment (Beveridge and Ames 1956).

Several benefit-cost analyses have been made recently of juniper control projects in Arizona (Clary et al. 1974). Juniper control was shown to be not economically feasible where gains in potential grazing capacity were less than 0.12 AUM per acre. Where the gain in potential grazing capacity is 0.27 AUM per acre, however, the total benefit to ranching amounts to as much as $23 per acre (7.0 percent interest), which gives a net positive difference of more than $3 per acre. Clary et al. (1974) conclude that, based on 1972 technology, costs, and values, identifiable economic benefits and costs come out about even for the more successful juniper control projects.

Fertilizer Applications

Fertilization of pinyon-juniper ranges in the Southwest has been limited to small-scale tests, mainly in south-central New Mexico. Blue grama range at Fort Stanton was fertilized with 40 or 60 pounds of nitrogen per acre each year from 1965 to 1971 (Dwyer 1971). Grass production more than doubled where 60 pounds of nitrogen was applied. Six-year average yields were:

	Grass production (*Lb/acre*)
No fertilizer	493
Fertilized with nitrogen:	
40 lb/acre	949
60 lb/acre	1,223

A 138-acre pasture at Fort Stanton was also fertilized with 40 pounds of nitrogen per acre for 3 years (Dwyer and Schickendanz 1971). Herbage production increased sufficiently to warrant doubling the stocking rate—from 12.5 acres per head for unfertilized range to 5.0 acres per head for fertilized. Gains of heifers over the 3 years averaged 23 pounds per acre on unfertilized range compared to 48 pounds on fertilized range.

Management Considerations

All factors considered, the best use of pinyon-juniper lands in the Southwest is to provide forage for grazing animals. Situated as they are between the desert and the pine forests, woodland ranges may hold the key to balancing livestock numbers with forage supplies in the Southwest. Although the possibilities for improving woodland ranges have not been fully explored, these ranges could conceivably support more livestock if they were improved to their maximum capability by plant control, seeding, fertilizing, proper stocking, and management. Some woodland ranges can definitely be improved through deferred, rotation, or other systems of grazing. Any rehabilitation program should be geared to the potential of the specific area to respond to either (1) grazing management to improve range condition, or (2) manipulation of the plant cover to increase forage production.

Manipulation of Tree Cover

A decision to manipulate the plant cover should be based on sound ecological principles. Areas with at least 15 inches of annual precipitation, moderately deep soils, slopes less than 15 percent, and fairly dense tree cover offer the best possibilities for manipulation.

Daniel et al. (1966) suggested using aerial photos to evaluate the potentials of pinyon-juniper areas for forage production. Percent crown canopy estimated from aerial photos can be in tree canopy-herbage production relationships to estimate potential forage production.

Besides considering potential productivity, the land manager must decide which tree stands can be optimally controlled by one of the several methods available. Factors that influence this decision are (1) rate of forage decline due to increases in tree growth, (2) rate of forage increase after control, and (3) rate of change of treatment costs. Decline of forage production due to increase in tree cover with time has been estimated from equations, as has the recovery of forage following tree control (Jameson 1971). The average recovery rate was found to be 92 pounds per acre per year from the time of tree control until the level of forage production without trees is reached (400 lb/acre for blue grama; 600 lb/acre for mid-grasses).

Rate of change of the costs of various control methods, including cabling and burning, also were calculated. According to Jameson (1971), the optimum time for a given control operation is when rate of change in benefits equals the rate of change in costs. The optimum cover for individual tree burning is 1 to 3 percent for all tree stands of 20 to 180 trees per acre. For cabling, the optimum is 4 to 6 percent tree cover; many stands suitable for cabling have already been treated.

The optimum cover for bulldozing increases with number of trees. On a short-grass site, for example, optimum cover for bulldozing ranged from 2 percent with 20 trees per acre to 12 percent with 200 trees per acre. The results of Jameson's study apply to variable-cost treatments. For a fixed-cost method, such as tree crushing, the timing is optimum when the rate of change in benefits is zero; that is, when the tree cover reaches a maximum and forage production is minimum—usually when the tree cover is 25 percent or more.

Control of sparse stands of pinyon-juniper for the primary purpose of improving browse production may not be warranted. Thus, on the North Kaibab Ranger District, production of cliffrose was 2.7 times greater where a thin pinyon-juniper stand (15 trees per acre) had been bulldozed 4 to 6 years earlier, but the total yield of cliffrose was only 3.5 pounds per acre more on the treated than on the untreated areas. This increase could hardly be very significant in terms of total needs of the deer (McCulloch 1966). Later studies in the same area revealed no increase in cliffrose density 11 years after tree control (McCulloch 1971).

Pinyon-juniper control areas should be kept relatively narrow so that deer using the created openings are never far from cover (New Mexico Inter-Agency Range Committee 1971). Ideally, the openings should not be more than ¼ mile wide. Abundance and condition of native shrubs in the understory influence the choice of control method. Chaining ordinarily does the least harm to useful shrubs such as cliffrose, mountainmahogany, and serviceberry, whereas other methods may practically destroy valuable understory plants unless the equipment operator has been trained.

Burning dense woodland on fairly rough terrain to improve range conditions for both cattle and deer may be an acceptable practice, according to McCulloch (1969). His studies of wildfires and prescribed burns over a 20-square-mile area on the Hualapai Indian Reservation showed live tree cover was completely destroyed by the fires. Despite the large acreage burned, only 5 percent of the burned areas were more than ½ mile from unburned woodland. Consequently, deer using the burned areas were never far from cover. Cliffrose, a major component of the understory on unburned areas, was virtually absent from the burned areas. Nevertheless, deer were more abundant on burned than unburned areas. Nonbrowse items made up 85 percent of the contents of deer rumens collected from burned areas in autumn. The large-scale burns may not have been optimum for deer, but they served the dual purpose of increasing food for deer and cattle.

Guidelines for Grazing Management

Management guidelines given by Humphrey (1955) for woodland ranges in Arizona include (1) leaving a third of the grass culms ungrazed at the end of the season, and (2) resting areas so that grasses can set seed and new seedlings can be established. He recommended resting woodland ranges in poor condition every summer, those in fair condition every other summer, and those in good condition once in 3 years. Pinyon-juniper ranges in good condition generally support a fairly dense understory of desirable grasses such as black, blue, and sideoats gramas, Indian ricegrass, Junegrass, western wheatgrass, galleta, and palatable shrubs, whereas those in poor condition support mainly thin stands of ring muhly, blue grama, and sand dropseed, together with many weeds and half-shrubs, including snakeweed, pingue, and rabbitbrush. Contrary to Humphrey (1955), Jameson (1970) claims snakeweed is unreliable as an indicator of range condition in the pinyon-juniper type.

Dual grazing by cattle and sheep offers possibilities for increasing livestock production. Studies on the Fort Stanton range, where blue grama comprised 66 percent of the forage available, wolftail 17 percent, and sideoats grama 5 percent, showed cattle consistently consumed more grass and sheep more of the forbs (Thelford et al. 1971). For both cattle and sheep, forbs were more important in the fall-spring, and grasses in the summer. The animals preferred sideoats grama over blue grama and wolftail.

Prairie Junegrass and bottlebrush squirreltail are preferred by yearling cattle during spring-fall grazing in the woodland type of northern Arizona (Clary and Pearson 1969). Junegrass was utilized 43 percent and squirreltail 40 percent compared with 33 percent for muttongrass, 30 percent for sideoats grama, and 5 percent for blue grama.

Range readiness in the pinyon-juniper type was investigated near Flagstaff (Jameson 1965b). Cool-season grasses such as muttongrass, Junegrass, squirreltail, and western wheatgrass begin active growth between March 10 and April 10 each year. Height growth of the cool-season grasses between April 10 and May 10 is reasonably predictable; squirreltail, western wheatgrass, and Junegrass grow about ½ inch and muttongrass about 1¾ inches a week. By adding expected growth to existing growth, the time at which these species will reach a given height can be predicted. For example, if grazing is to begin when western wheatgrass is 4 inches tall, and the height on April 10 is 2 inches the predicted date of range readiness would be 4 weeks later, or May 8. Warm-season grasses such as blue, sideoats, and black gramas, galleta, black dropseed, and spike muhly grow slowly from spring to mid-July. They grow rapidly in late July and August, depending largely on summer rains. Because they usually are grazed during the time of effective precipitation, forage production is difficult to predict.

Grazing systems should be designed to allow occasional rest for both the cool- and warm-season grasses. According to Jameson (1965b), three periods should be recognized: summer (July 10-October 15), winter (October 15-April 10), and spring (April 10-July 10). For most of the pinyon-juniper type, cool-season grasses need more protection than warm-season grasses. The period from April 10 to July 1 probably is the most critical for the cool-season species. If warm-season grasses are to be favored, they should be protected from grazing from about July 15 to October 15.

Blue grama growth in northern Arizona can be predicted at the earliest on August 15, according to Jameson (1965b). Maximum height usually is reached by September 12, so the range manager has a 4-week lead to estimate total growth. Maximum height will be about 1 inch plus 1½ times the height on August 15. If, for example, plants are less than 4 inches tall on August 15, they will be less than 7 inches tall by the end of the season; if there is 10 inches of growth on August 15, total height will be about 16 inches.

Blue grama yields are highly correlated with growing season and total annual precipitation in the pinyon-juniper type on Fort Stanton (Pieper et al. 1971). Correlation coefficients for alluvial loamy sites were as follows:

	Herbage production	
Precipitation	**All species**	**Blue grama**
Annual (Oct.-Sept.)	0.81	0.65
Growing season (June-Sept.)	.84	.71

Because production varies directly with precipitation, stocking rates can be adjusted on these alluvial loamy sites to avoid heavy grazing in years of below-average precipitation.

Correlating Grazing with Other Uses

Wildlife.—Pinyon-juniper woodlands are valuable to wildlife. The type provides protective cover and food, including juniper foliage and berries, pinyon nuts, and forage from understory shrubs, forbs, and grasses. Pinyon-juniper is especially important to deer. About one-fourth of the annual deer harvest in Arizona comes from the pinyon-juniper (McCulloch 1969). The type also is valuable to turkeys, elk, antelope, rabbits, squirrels, quail, and many non-game species of birds and mammals.

In the woodland type of southwestern New Mexico, Reynolds (1964) found shrub abundance was the most important factor influencing deer and elk use. Shrubs increased with number of trees to a density of about 150 trees per acre; in denser tree stands, number of shrubs decreased. Elk and deer preferred northeastern exposures. They used slopes up to 40 percent as much as level areas. Based on these results from Fort Bayard, Reynolds recommended coordinating livestock range-improvement practices with game habitat preservation by (a) clearing only slopes less than 15 percent, (b) leaving existing cover on north-east exposures, and (c) on areas reserved for game, removing or thinning trees where the stand exceeds 150 trees per acre.

Browse comprised 86 to 96 percent of mule deer diet during the fall-winter period in the pinyon-juniper type at Fort Bayard (Boeker et al. 1972). During spring and summer, deer used forbs to the extent that browse made up only 58 percent of the diet. The five leading browse species and their percentage contributions to mule deer diets were: mountainmahogany 33, oak 24, juniper 5, Wright silktassel 4, and skunkbush sumac 3. Mountain-mahogany and oak were most important mainly because of their availability. Results of these studies on Fort Bayard indicate habitat management should strive to maintain the mountainmahogany and oaks since they contribute most to deer nutrition (fig. 21). The junipers and pinyons, on the other hand, can be sacrificed from the standpoint of food contribution. The trees also appear unnecessary for cover where there is an adequate stand of shrubs (25 to 50 shrubs per acre).

Other studies on Fort Bayard show habitat for desert cottontails can be maintained during pinyon-juniper control by keeping 70 to 90 living shrubs and/or down, dead trees per acre (Kundaeli and Reynolds 1972). Under natural conditions, cottontails thrived where vegetation per acre averaged 85 trees, 85 shrubs, and 270 pounds of perennial grass. Overstory trees affect cottontails largely by suppressing the shrubs. Cottontails were fewer where shrubs had been suppressed to less than 85 plants per acre. Uprooting, piling, and burning all trees depressed cottontails. Leaving down, dead trees scattered through the control areas proved beneficial except where the density of living shrubs exceeded 70 to 90 per acre.

Figure 21.—Where mountainmahogany is abundant and the slopes are steep, the area should be managed primarily as wildlife habitat.

Water.—Opportunities for increasing usable water yield from the pinyon-juniper type are not promising (Dortignac 1960). Studies on pinyon-juniper watersheds showed that runoff constitutes only 2.2 percent of the annual precipitation near Santa Fe and only 4.5 percent near Gallup (Mexican Springs). Runoff in the New Mexico studies came mostly from intense convectional thunderstorms, as these average runoff figures indicate:

	Runoff	
Annual rainfall	**Santa Fe**	**Mexican Springs**
(*Inches*)	(*Inches*)	
<1.01	0.046	0.043
1.01-2.50	.131	.137
>2.50	.193	.335

Results from Arizona studies are similar. Streamflow averages only about 2 percent in the lower pinyon-juniper type, based on these data from Beaver Creek (Brown 1965):

	Annual precipitation class	
	Low	**High**
	(*Inches*)	
Lower pinyon-juniper type (Utah juniper)		
Precipitation	13.0	24.0
Runoff	0	.8
Upper pinyon-juniper type (Alligator juniper)		
Precipitation	14.0	30.0
Runoff	.3	5.4

Utah juniper areas contribute much more suspended sediment during periods of streamflow than do alligator juniper areas.

The amounts of rain and snow intercepted by Utah and alligator juniper crowns, and the amounts that reach the ground by throughfall and stemflow, vary with duration and intensity of storms and are predictable (Skau 1964a). Clearing juniper increases water available for producing forage, but has little effect on water yield, according to Skau (1964b). No change in water yield was detected after pinyon-juniper was removed by chaining from one-fourth of an area on sedimentary soils in eastern Arizona (Collings and Myrick 1966).

After several years of careful study of six treated and control Beaver Creek watersheds in central Arizona, Clary et al. (1974) concluded that: (1) mechanical methods of pinyon-juniper removal are not likely to increase water yield; (2) removal of pinyon-juniper overstory by herbicides can increase water yield; and (3) there has been no statistical verification of changes in flood peaks or water quality due to treatment.

Timber products.—The pinyon-juniper type in Arizona and New Mexico contains much wood. For New Mexico alone the estimate is 1.7 billion cubic feet (Choate 1966). Only a small percentage of this wood is utilized. Principal wood products are firewood, fenceposts, and charcoal; other products include pinyon nuts and Christmas trees.

Firewood yields vary with density, age, and composition of the stand. Howell (1940) reported yields averaged 11.4 cords per acre. A study in New Mexico revealed wholesale buyers paid $14 to $18 per cord;

retail prices ranged from $25 to $36 per cord (Sowles 1966). The market for pinyon fireplace wood seems to be growing, whereas that for juniper is diminishing. Profits depend on type of operation and market area; Albuquerque is generally less profitable than Phoenix (LeBaron 1968).

Juniper fenceposts have been an important product of the pinyon-juniper type for many years, because of their outstanding natural durability. In recent years the market for juniper posts has declined; however, Howell (1941) estimated about 46 posts per acre in uncut stands in Arizona and New Mexico.

Charcoal consumption is on the increase, but making charcoal from pinyon and juniper is a speculative venture. Yields of 30 to 35 percent have been obtained (Barger and Ffolliott 1972). Costs of production vary with type of equipment used, capacity, species of wood, proximity to wood source, and labor.

The pinyon nut crop averages 1 to 2 million pounds annually (Little 1941). Pinyon trees produce nuts only at intervals of 4 to 7 years. Crop years differ from area to area, however, so that good crops occur somewhere every year. The better natural stands may yield 300 pounds of nuts per acre during a good year. Pickers usually receive 50 cents to a dollar per pound (1975 rate).

Pinyons are a popular Christmas tree (fig. 22). For example, in 1964, pinyons comprised about 25 percent of all Christmas trees in the six-State area of New Mexico, Arizona, Colorado, Wyoming, Utah, and Nevada, although the demand for pinyons has declined since then (Barger and Ffolliott 1972). More than 6,000 salable Christmas trees were found on a 640-acre area in northern Arizona, and an additional 3,000 small trees (up to 3 feet) were judged to be salable in the future.

A system of grading has been developed specifically for pinyons based on form class, symmetry, foliage density, and color. Quality of the trees can be improved by cultural treatments such as thinning and shearing. Management primarily for Christmas trees, including silvicultural practices such as stump culture, pruning, and weed control, has been advocated for areas with deep soils where growth form of pinyons is suitable (Jensen 1972).

According to Barger and Ffolliott (1972), utilization of wood products should be coordinated with management of the other resources, particularly with programs for controlling the trees. Live, standing pinyons, for example, should be harvested before the control operations because pinyon is nondurable and deteriorates quickly. Junipers, on the other hand, remain durable for many years and can be harvested on the ground after chaining, pushing, or other treatment. Besides its common use for fuel and fenceposts, juniper might be used for chemical, fiber, or chip products such as charcoal, pulp, and particleboard. The tree crusher leaves logs in fireplace lengths, so that tree-crushed areas are popular among woodhaulers, who also remove or knock down much of the debris that would otherwise interfere with grazing animals.

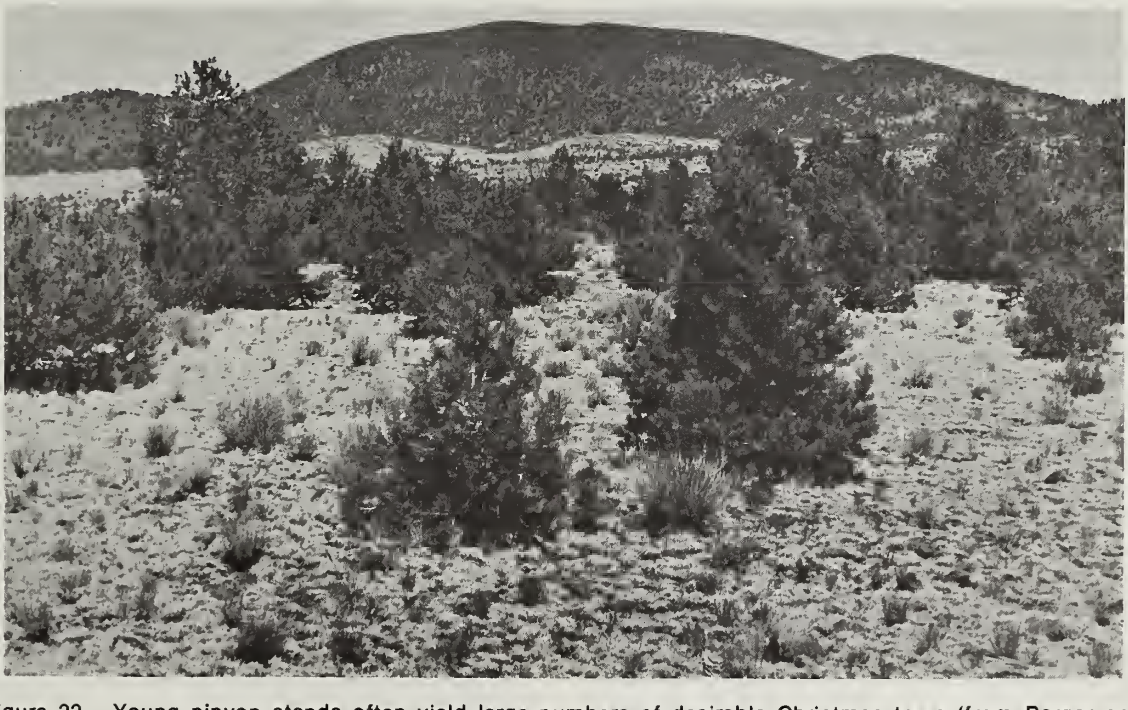

Figure 22.—Young pinyon stands often yield large numbers of desirable Christmas trees (from Barger and Ffolliott 1972).

Conclusions and Recommendations

The pinyon-juniper type in the Southwest is important because of its size, if for no other reason. It covers a significant part of Arizona and New Mexico, and has a long history of use and abuse. It has been providing people with useful products and furnishing feed for animals for centuries. As the population of the Southwest expands, pressures on the resources of the type are increasing.

In characterizing the pinyon-juniper, a rather obvious feature is its diversity. It grows under a variety of climates and on a variety of topography, parent material, and soil. The plant threads binding the communities together, of course, are the pinyon and juniper trees themselves, which grow in many different densities, proportions, and sizes.

Sufficient information is on hand to broadly characterize the major pinyon-juniper communities. Subtypes can be identified in a general way, based on species composition of the overstory. The climate has been classified, mainly for revegetation purposes. Geology and soils are known, again in a general way, and the potentials of some soils have been estimated.

The ecological information presently available is useful, but further research is warranted. A more intensive classification of the type, together with more accurate maps, is needed. From the standpoint of planning and management, it would be helpful if woodland areas were classified according to their forage-producing potential and grazing value. This would require autoecological studies of the physiology, growth habits, and reproductive characteristics of the undesirable as well as desirable species. The interrelationships among various climatic, edaphic, and other site factors as they influence plant growth need to be studied to provide bases for predicting the potentials for improving productivity.

A general problem, which overshadows many other problems, is the widespread deterioration of woodland ranges in the Southwest. The unsatisfactory conditions can be traced to the long history of overgrazing, which reduced the herbaceous ground cover and led to increased tree density. Statistics indicate National Forest woodland ranges are mostly in poor and fair condition; less than 10 percent are in good condition. Steps are being taken, however, to improve woodland range through tree control, revegetation, and systems of grazing.

Much of the available information pertaining to the Southwest's pinyon-juniper type relates to northern Arizona, due to the concentration of range research efforts there in the past. Other information stems from research in southern New Mexico at Fort Stanton, which is representative of woodland range generally more productive than those in northern New Mexico or Arizona.

Relatively large areas of pinyon-juniper in the Southwest have been neglected from the standpoint of range management research. The scope of the research likewise has been somewhat narrow in that, for most woodland ranges, we have only fragmentary information on such vital aspects of range management as proper number of animals, season of grazing, water development, fencing, salting, animal nutrition and breeding, and operational costs and returns.

General guidelines are available for judging the condition of pinyon-juniper ranges, and for management. Resting areas from grazing during the growing season at 1- to 3-year intervals has been recommended. Warm-season grasses are favored by summer deferment, while cool-season grasses respond to protection from grazing during the spring. Range readiness has been determined for pinyon-juniper ranges near Flagstaff; similar information is needed for other areas.

Summer rainfall directly affects the growth of blue grama—the most common grass on woodland ranges—but the predictive value of the relationship between precipitation and blue grama growth is uncertain. Further studies are needed to determine the possibilities of developing prediction equations as aids in estimating forage production and stocking rates in advance of the grazing season. These predictions might be made from soil moisture instead of from precipitation records.

The best use of pinyon-juniper in the foreseeable future is as range for grazing animals. If developed to their potential, pinyon-juniper ranges undoubtedly could furnish forage for more animals. The full potential of these ranges is rarely realized. In the more open stands of trees, much can be accomplished through grazing management alone; forage production can be increased substantially through deferred grazing. The denser stands support a relatively sparse understory, however, and little increase in forage can be achieved by grazing management alone; elimination of all or part of the tree overstory is necessary for significant improvement in forage production. Pinyon-juniper stands on fairly level terrain and moderately deep soils offer the best possibilities for conversion to grassland.

More information is available relating to the control of pinyon-juniper than to other aspects of management. Early attempts at cabling produced only transitory benefits; small trees missed by the cable grew rapidly, and in the end, the treated areas were a tangle of down, dead trees intermingled with a greater number of live trees than existed before cabling. Now with the experience of past failures and successes, reasonably reliable guidelines have been developed. Criteria and standards for pinyon-juniper control have been defined. Responses to control also have been studied in some detail, and situations to be avoided have been pointed out. Because of the ready availability of these guidelines, most land managers are familiar with the various methods and results to be expected. They must select sites carefully, however, and analyze characteristics of the tree stands before deciding which method to use. An increase in livestock grazing capacity of about 0.21 to 0.32 AUM per acre is indicated for the more successful pinyon-juniper conversion projects, but much lower increases are typical when conversions are attempted on sites with a low potential for improvement (Clary et al. 1974).

Guides are available for helping the land manager decide which tree stands can be optimally controlled by one of the several methods available. Factors that influence this decision are the rate at which forage is declining due to increased tree growth, the rate of forage increase expected after tree control, and the rate of change in treatment costs. The time for a given control operation is optimum when the rate of change in benefits equals the rate of change in costs. An example given by Jameson (1971) is the 1 to 3 percent optimum cover for individual tree burning.

The benefits of pinyon-juniper control have been analyzed in economic terms, but further studies are needed. Comparative cost data should be updated at 2- to 3-year intervals. Fairly thorough economic analyses are needed for representative areas to ascertain the feasibility of certain range improvement practices. Analysis of a number of pinyon-juniper conversion attempts suggest that, under 1972 economic conditions, the more successful projects just about break even from a benefit-cost standpoint (Clary et al. 1974). Projects that are less successful than the best will yield a negative net return.

Ecological evidence points to suppression of fire as a major factor influencing the spread of juniper in northern Arizona. It seems logical, therefore, that prescribed burning would be a useful tool in converting juniper stands to grassland. This has been successfully demonstrated in some areas. Burning individual trees has proved effective for scattered small trees. Broadcast burning of dense, mature stands requires special conditions that are hazardous. Further research on prescribed burning is warranted in view of the encouraging results obtained thus far.

A fair amount of information is available concerning species and methods for seeding pinyon-juniper ranges. Research results, however, indicate seeding woodland ranges in the Southwest is a rather risky venture. Due to wide differences among sites and highly variable weather, the best species and methods to use are uncertain. Additional research is justified to clarify some of the problems and to develop more dependable guidelines.

The importance of the pinyon-juniper as wildlife habitat is well recognized, mainly for deer, but also for elk, turkey, and other species. Overuse by heavy concentrations of deer has deteriorated some areas so that nearly all browse plants are hedged or highlined. Competition between game and livestock is sometimes severe, particularly on ranges in poor condition. Shrub abundance is a key factor influencing the use of pinyon-juniper ranges by game animals. Recommendations for improving wildlife habitat are to control trees on the more gentle terrain (less than 15 percent slope) and deeper soil, and leave the ridges and steeper slopes untreated, especially northeast slopes. Other guidelines include keeping the cleared areas no more than ¼ mile wide, and doing minimal damage to understory browse plants. The response by deer to relatively large-scale pinyon-juniper treatments on the Beaver Creek watersheds in central Arizona has been, on the average, neutral (Clary et al. 1974). All treatments increased the production of preferred plants, but cover must be available nearby if deer are to use the areas.

Only limited information is available concerning the effects of grazing on runoff and erosion from pinyon-juniper ranges. As a general rule, heavy grazing increases soil erosion from most range types, and aggravates sedimentation problems in the Southwestern river basins. Grazing management appears to affect runoff and water yield from the pinyon-juniper type only slightly, however. The dangers of soil erosion are greatest during the early stages of conversion from trees to grass. Replacement of pinyon-juniper by grass eventually results in less soil loss, but the effects on water yield are negligible.

Coordinating the various land uses holds promise of improving the management of pinyon-juniper in the Southwest. Utilization of wood products is related either directly or indirectly to the production or recovery of the other woodland resources. For example, when trees are controlled to increase forage production, large quantities of firewood are made easily available to woodhaulers. By the same token, areas of pinyon known to be favored by local people for nut collection should be left uncleared.

In the final analysis, the evidence suggests the Southwestern pinyon-juniper type can be modified and managed for an optimum mix of products. Forage for livestock and habitat and food for wild animals are the main products, but also important are fireplace wood, fenceposts, pinyon nuts, Christmas trees, and esthetically pleasing surroundings—for recreation and living—for people. All of this can be accomplished through proper selection of conversion sites, planning, and management. The various phases of this overall program have not been sufficiently refined to permit wide application. Further research is required. But as the needs and demands intensify, models will be developed that include most of the major factors (such as climate, geomorphology, soils, crown cover and density of trees, and understory vegetation) that affect potential productivity and treatability. Then maps will be prepared delineating areas according to their potentials. The ultimate result should be wiser use and better management of the resource.

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Common and Botanical Names of Plants Mentioned
(Alphabetically by common name)

Actinea, Cooper	*Hymenoxys cooperi* Cockerell
Alfalfa	*Medicago sativa* L.
Algerita	*Berberis fremontii* Torr.
Bluestem, Turkestan (yellow)	*Bothriochloa (Andropogon) ischaemum* (L.) Keng
Burnet	*Sanguisorba minor* Scop.
Cliffrose	*Cowania mexicana* D. Don.
Dropseed, black	*Sporobolus interruptus* Vasey.
Dropseed, sand	*Sporobolus cryptandrus* (Torr.) A Gray
Galleta	*Hilaria jamesii* (Torr.) Benth.
Goldeneye, annual	*Viguiera annua* (Jones) Blake
Goosefoot, ragleaf	*Chenopodium incisum* Poir.
Grama, black	*Bouteloua eriopoda* Torr.
Grama, blue	*Bouteloua gracilis* (H.B.K.) Lag.
Grama, sideoats	*Bouteloua curtipendula* (Michx.) Torr.
Junegrass, prairie	*Koeleria cristata* (L.) Pers.
Juniper alligator	*Juniperus deppeana* Steud.
Juniper, one-seed	*Juniperus monosperma* (Engelm.) Sarg.
Juniper, Rocky Mountain	*Juniperus scopulorum* Sarg.
Juniper, Texas	*Juniperus texensis* VanMelle
Juniper, Utah	*Juniperus osteosperma* (Torr.) Little
Lovegrass, Boer	*Eragrostis chloromelas* Steud.
Lovegrass, Lehmann	*Eragrostis lehmanniana* Nees
Lovegrass, weeping	*Eragrostis curvula* (Schrad.) Nees
Mountainmahogany	*Cercocarpus montanus* Raf.
Muhly, ring	*Muhlenbergia torreyi* (Kunth) Hitchc.
Muhly, spike	*Muhlenbergia wrightii* Vasey
Muttongrass	*Poa fendleriana* (Steud.) Vasey
Oak, gray	*Quercus grisea* Liebm.
Oak, Gambel	*Quercus gambelii* Nutt.
Pine, ponderosa	*Pinus ponderosa* Laws.
Pingue	*Hymenoxys richardsonii* (Hook.) Cockerell
Pinyon, common	*Pinus edulis* Engelm.
Pinyon, Mexican	*Pinus cembroides* Zucc.
Pinyon, singleleaf	*Pinus monophylla* Torr. & Frem.
Rabbitbrush	*Chrysothamnus* spp.
Ricegrass, Indian	*Oryzopsis hymenoides* (Roem. & Schult.) Ricker
Ricegrass, little	*Oryzopsis micrantha* (Trin. & Rupr.) Thurb.
Sage, black	*Artemisia nova* A. Nels.
Sagebrush, big	*Artemisia tridentata* Nutt.
Serviceberry	*Amelanchier* spp.
Saltbush, fourwing	*Atriplex canescens* (Pursh) Nutt.
Silktassel, Wright	*Garrya wrightii* Torr.
Snakeweed, broom	*Gutierrezia sarothrae* (Pursh) Britt. & Rusby
Squirreltail, bottlebrush	*Sitanion hystrix* (Nutt.) J. G. Smith
Sumac, skunkbush	*Rhus trilobata* Nutt.
Sweetclover, yellow	*Melilotus officinalis* (L.) Lam
Threeawns	*Aristida* spp.
Wheatgrass, crested	*Agropyron desertorum* (Fisch.) Schult.
Wheatgrass, intermediate	*A. intermedium* (Host) Beauv.
Wheatgrass, western	*A. smithii* Rydb.
Wheatgrass, pubescent	*A. trichophorum* (Link) Richt.
Wildrye, Russian	*Elymus junceus* Fisch.
Wolftail	*Lycurus phleoides* H.B.K.

Springfield, H. W.
1976. Characteristics and management of southwestern pinyon-juniper ranges: The status of our knowledge. USDA For. Serv. Res. Pap. RM-160, 32 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

The pinyon-juniper type, characterized by diversity of climate, soils, and topography, covers about 30 million acres in Arizona and New Mexico. The major problem is widespread deterioration of the range resources due to overgrazing and increases in tree density. General guidelines are available for judging the condition and grazing management of pinyon-juniper ranges, as well as for deciding where and how to control the trees for range and wildlife habitat improvement. Although further research is warranted, information is adequate to modify and manage the type to provide an optimum mix of products. These include forage for livestock, ana tooa and habitat for wild animals as the main products; also included are fireplace wood, fenceposts, pinyon nuts, and Christmas trees.

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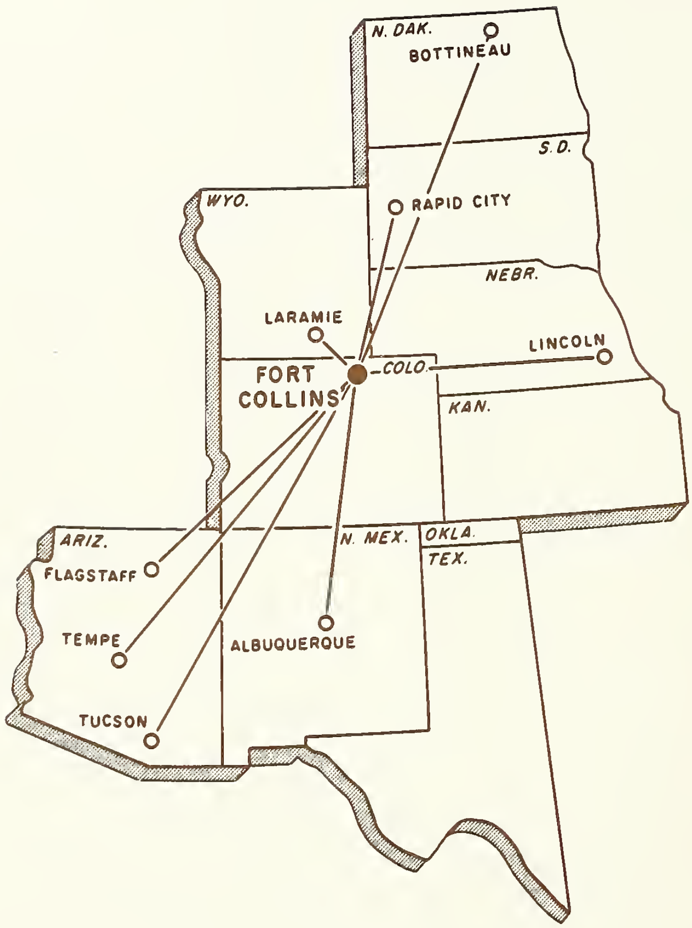
Keywords: Range management, pinyon-juniper type, forage, tree control, *Pinus* sp., *Juniperus* sp.

Although this report discusses research involving pesticides, such research does not imply that the pesticide has been registered or recommended for the use studied. Registration is necessary before any pesticide can be recommended. If not handled or applied properly, pesticides can be injurious to humans, domestic animals, desirable plants, fish, and wildlife. Always **read** and **follow** the directions on the pesticide container.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